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Farm Production of Sorgo Sirup



ANY AVERAGE of about 15,000,000 gallons of sorgo sirup is made in the United States each year. Sorgo sirup, often termed "sorghum molasses", is a valuable subsistence and small cash crop on thousands of farms. Sirup of better and more uniform quality, however, would have more extensive marketing possibilities and bring a higher price.

This bulletin describes important improvements recently developed in the method of making sorgo sirup. Starting with the harvesting of the sorgo, it tells how to make sorgo sirup by the methods recommended for practical use on the farm. It describes a lay-out for the plant and the equipment needed for efficient operation, and gives the cost of materials, equipment, and labor required to construct and operate a sirup-making outfit. It tells how to avoid many of the difficulties of sirup making, how to make sirup on shares, and how to use the byproducts. Finally, it gives suggestions for more efficient marketing.

Tables showing the composition of the juice and sirup from typical varieties of sorgo and statistics on the production of sirup are included.

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FARM PRODUCTION OF SORGO SIRUP

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USE OF SORGO FOR SIRUP

SORGO is called sorghum in many parts of the country, and until recently the sirup from sorgo was generally known as sorghum sirup. Sorgo is the name now preferred by the United States Department of Agriculture for the varieties of sorghum that have abundant sweet juice, as distinguished from the grain-producing varieties.

On many thousands of small farms sorgo is considered a valuable subsistence and small cash crop. Sorgo production in the United States is more widely distributed than the production of sugarcane or sugar beets. Sorgo is easy to cultivate, and when the growing season is favorable the crop gives reasonable returns and contains enough total sugars to yield sirup at a satisfactory profit. At one time it was believed that sorgo had value in the production of sugar, and from 1860 to 1890 much experimental work, both on a small scale and a factory scale, was done in the attempt to develop this industry. As compared with sugarcane and sugar beets, however, the yield of sorgo and sugar per acre is low; in most localities the sugar-making season would be short; and the crop is relatively unreliable and perishable from the standpoint of sugar production. Sorgo juice, moreover, contains gummy materials, starch, and comparatively large quantities of sugars other than the ordinary sugar of commerce (sucrose), which retard and sometimes prevent crystallization. Although improved methods of clarification have been developed, the yields of crystallized sugar have usually been found too small to justify establishing this as a separate and independent sugar industry.

The term "sorghum molasses", often applied to sorgo sirup, does not properly describe the product. It probably came into use because poor-quality sorgo sirup, like molasses, is dark and thick and flows slowly. Sirups such as sorgo, sugarcane, and maple-sap sirups are made by evaporating the plant juice or sap without removing any of the sugar. Molasses is the liquid which remains after part of the sugar has been removed, as in the manufacture of cane sugar. When no sugar is made from sorgo, the use of the term "molasses" in this connection is incorrect.

Sorgo sirup of the best quality makes an excellent table sirup, as it is light in color and has a mild and pleasant flavor. It is especially well liked by those who are accustomed to its characteristic flavor.

PRODUCTION OF SORGO SIRUP IN THE UNITED STATES

The earlier production of sorgo sirup in the various States is indicated by the figures in table 1, which were obtained from reports of the United States Bureau of the Census. These figures are only approximate, as much of the sirup made on a small scale was probably not reported.

TABLE 1.—*Production of sorgo sirup in the United States (1859-1909)*

State	1909	1899	1889	1879	1869	1859
	<i>Gallons</i>	<i>Gallons</i>	<i>Gallons</i>	<i>Gallons</i>	<i>Gallons</i>	<i>Gallons</i>
Alabama	809,361	1,168,868	1,242,689	1,163,451	267,269	55,653
Kentucky	2,733,683	1,277,206	2,094,962	2,962,965	1,740,453	356,705
Tennessee	2,076,339	2,047,655	2,542,533	3,776,212	1,254,701	706,663
Georgia	740,450	767,024	1,342,803	981,152	374,027	103,490
Mississippi	622,356	1,162,269	972,216	1,062,140	67,509	1,427
Texas	448,185	877,232	1,749,910	432,059	174,509	112,412
Arkansas	1,140,532	1,223,691	1,868,952	1,118,364	147,203	115,604
Missouri	1,788,391	1,990,987	2,721,240	4,129,595	1,730,171	796,111
North Carolina	1,099,346	1,419,570	1,268,946	964,662	621,855	263,475
South Carolina	262,452	478,190	559,216	281,242	183,585	51,041
Oklahoma	514,807	179,272	31,299			
Indiana	965,086	579,061	751,308	1,741,853	2,026,212	881,049
Virginia	441,189	555,321	546,328	564,558	329,155	221,270
Iowa	250,205	521,212	1,386,605	2,064,020	1,218,636	1,211,512
Illinois	977,238	625,939	1,110,183	2,265,993	1,960,473	806,589
West Virginia	604,201	450,777	512,747	817,168	780,829	
Ohio	354,131	341,523	547,630	1,229,852	2,023,427	779,076
Wisconsin	139,667	160,414	219,070	314,150	74,478	19,854
Kansas	260,680	735,787	1,484,937	1,429,476	449,409	87,656
Minnesota	145,934	157,605	340,792	543,369	38,735	14,178
Louisiana	47,029	48,727	107,763	33,777	180	
Florida	22,177		10,461	10,199		
Utah	21,847	28,017	24,293	58,221	67,446	25,475
Michigan	21,350	24,059	45,524	102,500	94,686	86,953
Nebraska	14,644	92,413	634,146	246,047	77,598	23,497
New Mexico	5,289	2,812	3,510	251	1,765	1,950
Delaware	4,517	8,952	3,371	25,136	65,908	1,613
California	4,330	8,671	1,670	2,459	333	552
Arizona	3,967	9,031	4,808	5,771		
Pennsylvania	2,555	6,514	33,708	69,767	213,373	22,749
Colorado	2,547	2,661	19,964	3,227		
South Dakota	2,030	9,859	29,372	¹ 17,012	¹ 1,230	¹ 20
Maryland	1,782	4,058	4,732	19,837	28,563	907
Oregon	1,374	2,473	2,706	2,283		315
Nevada	1,266	1,465	930	350	3,651	
Washington	634	438	1,125	1,472	612	
Idaho	407	1,393	3,093	36		
Montana	223	100				
North Dakota	102	114	10	⁽²⁾	⁽²⁾	⁽²⁾
New Jersey	35	450	281	1,261	17,424	396
New York	14	973	8,305	1,134	7,832	516
Wyoming			120			
Connecticut			214	1,163	6,832	395
Maine			152			
New Hampshire			50			
Vermont			45			
Massachusetts				18		
Rhode Island					20	20
Total	16,532,382	16,972,783	24,235,219	28,444,202	16,050,089	6,749,123

¹ Dakota Territory.

² Included in Dakota Territory; reported under South Dakota.

Statistics obtained by the United States Department of Agriculture show the following total production of sorgo sirup in the United States from 1919 to 1936:

	Gallons		Gallons
1919	39, 413, 000	1928	25, 630, 000
1920	49, 505, 000	1929	9, 256, 000
1921	45, 566, 000	1930	8, 916, 000
1922	36, 440, 000	1931	17, 818, 000
1923	32, 001, 000	1932	15, 209, 000
1924	25, 004, 000	1933	14, 961, 000
1925	24, 926, 000	1934	13, 788, 000
1926	34, 547, 000	1935	12, 438, 000
1927	30, 268, 000	1936	11, 848, 000

COMPOSITION OF SORGO JUICE

The results of typical analyses of juice from several varieties of sorgo grown in various places are given in table 2. The proportions of sucrose and invert sugar differ with the variety of sorgo, its maturity, the kind of growing season, and the geographical location where it is grown.

TABLE 2.—*Composition of the juice from different varieties of sorgo*

Variety and locality	Density	Sucrose	Invert sugar	Total sugar
Sumac:	[°] Baume	Percent	Percent	Percent
Biloxi, Miss.	8.1	4.07	7.37	11.44
Do.	10.1	10.93	3.21	14.14
Dalhart, Tex.	10.6	11.34	3.49	14.83
Do.	8.6	2.88	10.90	13.78
Brownsville, Tex.	9.0	8.52	4.74	13.26
Do.	8.0	4.26	6.70	10.96
Planters:				
Biloxi, Miss.	9.7	10.59	1.91	12.50
Arlington, Va.	9.7	2.98	10.70	13.68
Do.	11.3	4.15	11.69	15.84
Compton, Calif.	9.7	9.27	3.28	12.55
Monetta, S. C.	11.6	14.47	2.84	17.31
Do.	12.2	15.38	1.74	17.12
Brownsville, Tex.	7.3	5.58	3.86	9.44
Do.	7.9	8.22	2.05	10.27
Dalhart, Tex.	8.4	4.15	5.78	9.93
Do.	8.6	3.17	6.54	9.71
Red amber:				
Biloxi, Miss.	9.3	9.57	2.72	12.29
Arlington, Va.	9.2	.75	12.57	13.32
Do.	10.0	3.02	11.65	14.67
Monetta, S. C.	10.4	6.41	8.70	15.11
Compton, Calif.	11.9	1.43	14.46	15.89
Dalhart, Tex.	6.3	1.88	6.32	8.20
Brownsville, Tex.	8.3	4.64	6.87	11.51
Do.	7.4	1.81	7.64	9.45
Minnesota amber:				
Biloxi, Miss.	10.7	12.89	1.72	14.61
Arlington, Va.	10.0	3.54	11.15	14.69
Do.	10.5	4.26	11.40	15.66
Compton, Calif.	7.5	5.77	2.95	8.72
Monetta, S. C.	10.7	13.00	2.03	15.03
Dalhart, Tex.	7.4	4.98	4.54	9.52
Do.	8.5	4.82	6.78	11.60
Brownsville, Tex.	7.2	5.01	4.18	9.19
Do.	8.0	4.37	6.98	11.35
Orange:				
Biloxi, Miss.	10.3	12.32	1.88	14.20
Arlington, Va.	8.1	2.86	7.35	10.21
Do.	10.5	1.66	14.62	16.28
Compton, Calif.	9.2	7.99	3.38	11.37
Monetta, S. C.		14.30	1.75	16.05
Do.	12.7	15.53	2.14	17.67
Dalhart, Tex.	6.2	1.70	5.72	7.42
Brownsville, Tex.	6.8	2.64	5.91	8.55
Do.	9.6	8.14	5.35	13.49
Honey:				
Biloxi, Miss.	8.6	8.22	4.44	12.66
Arlington, Va.	11.0	3.58	13.57	17.15
Do.	11.2	11.46	4.48	15.94

TABLE 2.—*Composition of the juice from different varieties of sorgo—Continued*

Variety and locality	Density	Sucrose	Invert sugar	Total sugar
Honey—Continued.				
Compton, Calif.	° Baumé 11.6	Percent 12.59	Percent 1.50	Percent 14.09
Dalhart, Tex.	9.7	1.73	11.97	13.70
Brownsville, Tex.	8.3	5.66	5.78	11.44
Do.	8.7	8.44	3.42	11.86
Gooseneck:				
Biloxi, Miss.	8.9	8.67	4.42	13.09
Arlington, Va.	8.7	3.84	8.80	12.64
Compton, Calif.	8.5	7.39	2.91	10.30
Dalhart, Tex.	10.5	10.48	4.63	15.11
Colman:				
Compton, Calif.	11.9	13.79	1.12	14.91
Monetta, S. C.		15.30	1.28	16.58
Do.	11.2	14.25	1.93	16.18
Collier:				
Compton, Calif.	10.9	12.14	2.12	14.26
Monetta, S. C.	13.7	18.39	.61	19.00
Do.	14.0	18.24	.92	19.16
Average.	9.6	7.62	5.62	13.24

HARVESTING

The stage at which the sugar content of sorgo is greatest has been the subject of much investigation. The figures in table 3 are the averages of about 2,740 analyses of sorgo made at different stages of growth.

TABLE 3.—*Sugar content of juice from sorgo at different stages of growth* ¹

Stage of growth when cut	Sucrose	Invert sugar
Panicles just appearing	Percent 3.51	Percent 4.50
Panicles entirely out	5.13	4.15
Flowers all out	7.38	3.86
Seed:		
In milk stage	8.95	3.19
Doughy, becoming dry	10.66	2.35
Dry, easily split	11.40	2.03
Hard	13.72	1.56

¹ COLLIER, P. SORGHUM: ITS CULTURE AND MANUFACTURE ECONOMICALLY CONSIDERED AS A SOURCE OF SUGAR, SYRUP, AND FODDER. Page 198. Cincinnati. 1884.

During the time the seed is in the late milk to the soft- or medium-dough stage, sorgo is in the best condition for making sirup of good quality. Earlier than this it is too green, and the resulting sirup has a green taste. If cut when the seeds are very hard, the starch content of the juice is higher, the juice may be difficult to clarify, and the flavor of the sirup is not so good, owing largely to the starch, which causes slow boiling and scorching (pp. 6, 29).

The harvesting should progress with the mill work, no more sorgo than can be worked in 2 days being stripped and cut at one time. Sorgo deteriorates rather rapidly after harvesting, a portion of the sugar becoming inverted. Moreover, when the weather is hot and dry, moisture is evaporated from the stalks, so that the extraction of juice is lower, resulting in reduction of sirup yield.

When the weather is cold the stalks may, if necessary, be cut and shocked. A freeze severe enough to congeal the water in the cells of the stalk will render sorgo unfit for sirup making immediately after thawing, as freezing breaks the cells and when they are thawed decomposition quickly sets in. A frost just severe enough to kill the leaves will not hurt ripe sorgo materially, but it will spoil immature sorgo. Frosted sorgo, however, like frozen sorgo, should be worked up as soon as possible. In Louisiana, sugarcane is windrowed when a killing frost or freeze is expected, that is, it is cut and laid on the ground between the rows, the leaves serving as a protection. In windrowed sorgo, however, if the weather is warm during the middle of the day, the leaves on the stalks soon produce heating of the pile and decomposition sets in. Both frosting and heating impair the flavor of the sirup. Some believe that by shocking the stalks without removing the leaves and heads, sorgo may be kept in good condition for some time. This should be done only during cool weather, for even when standing in shocks it may heat.

TOPPING AND STRIPPING

Cutting may be done by hand or with a harvester. As a rule, before the stalks are cut, the leaves are struck off with a wooden paddle or raked off with a two-pronged iron tool. Sometimes, however, they are not removed until after cutting. When harvested by hand, the individual stalks are cut about 6 inches from the ground, the bottom joint being purposely discarded, and laid across the rows with all the heads in the same direction. With a harvester and binder, the cutting and binding in bundles form one operation, and all the seed heads are at one end of the bundle.

In making a good grade of sorgo sirup, all leaves and seed heads should be removed from the stalks. The seed heads are usually left in the field to be collected after the harvest. If ground, the seed heads, which contain about 60 percent of starch, would increase the starch content of the juice. Grinding the green leaves increases the objectionable nonsugar content of the juice, such as coloring matter and bitter principles, and tends to give sirup of poor color and flavor. Suckers should be discarded for the same reason. Moreover, leaves which have become dry have a tendency to absorb juice as it is pressed from the stalks, thus decreasing the yield of juice and sirup. In removing the seed heads, it is advisable to cut off at least two of the upper joints of the stalk, not counting the peduncle. As many as three or four top joints are sometimes discarded if it is practicable to use this portion of the crop for silage, as it contains much starch and mineral matter and a relatively high acidity (table 4), all of which have been found objectionable in making the best-quality sirup. Proper topping improves the quality of sirup, and it does not make the yield unsatisfactory from an economic standpoint when the discarded portion can be efficiently used for animal-feeding purposes.¹

¹The authors gratefully acknowledge the cooperation of J. R. Ricks, director, and W. R. Perkins, assistant director, Mississippi Agricultural Experiment Station, in supplying working facilities and in connection with the agronomic work of this investigation.

TABLE 4.—*Composition of sirup made from various parts of the stalk of Gooseneck sorgo at different stages of growth*

MILK STAGE, GREEN

Internode no. ¹	Sucrose	Invert sugar	Mineral matter	Organic nonsugars	Starch	Acidity ²
	Percent	Percent	Percent	Percent	Percent	
1-2.....	15.53	50.26	3.26	6.57	0.38	2.10
3-4.....	19.60	51.17	1.66	3.30	.27	1.60
5-6.....	21.22	50.18	1.06	3.31	.23	.60
7-8.....	18.90	52.72	1.10	3.09	.19	.50
9-10.....	5.72	65.51	1.32	3.29	.16	.75
11-12.....	4.35	66.14	1.69	3.75	.07	.75

DOUGH TO RIPE STAGE³

1-2.....	35.44	30.73	3.91	5.46	0.46	1.95
3-4.....	38.30	31.29	2.04	3.99	.38	1.05
5-6.....	30.18	40.59	1.33	3.61	.29	.85
7-8.....	21.23	50.07	1.39	3.15	.17	.75
9-10.....	16.50	54.81	1.73	2.87	.09	.80
11-12.....	16.01	54.96	1.83	3.12	.08	.75

OVERRIPE STAGE

1-2.....	41.44	23.84	4.01	5.85	0.86	2.15
3-4.....	43.68	24.68	2.05	4.77	.82	1.30
5-6.....	37.80	31.38	1.45	4.61	.76	1.05
7-8.....	33.25	35.99	1.63	4.55	.58	1.00
9-10.....	24.61	44.48	1.94	4.53	.44	1.00
11-12.....	25.95	42.66	2.42	4.53	.44	1.00

¹ Internodes 1 and 2 are the top of the stalk, and 11 and 12 are the bottom.² Expressed as cubic centimeters of 0.1 normal NaOH per gram of solids.³ Considered best for sirup.

The composition of sirup made from various parts of the stalk at different stages of growth is shown in table 4. The density of these sirups was originally about 76° Brix or 40.5° to 41° Baumé, measured at ordinary temperature. The original analytical data were recalculated to an exact 76° basis to make them strictly comparable. Sirup having a total solids content of 76 percent has a moisture content of 24 percent.

YIELD PER ACRE

The yield of sorgo may be as much as 15 tons or as little as 4 tons an acre. Figure 1 shows a good stand of sorgo just before harvesting. A good crop is 8 to 10 tons of properly topped and stripped stalks. With a three-roller mill, a ton of sorgo should produce from 700 to 1,200 pounds of juice. This gives from 8 to 20 gallons of finished sirup, varying with the richness of the juice. Assuming 10 tons as the yield, from 80 to 200 gallons of sirup to the acre may be obtained, although the yield per acre commonly reported ranges from about 75 to 150 gallons. The yield of sirup depends upon the kind of mill, the are used in the milling and manufacturing processes, and particularly upon the variety of sorgo, the attention given to seeding and cultivating, and the kind of growing season.

LOCATION, LAY-OUT, AND SIZE OF THE PLANT

The sirup maker should consider location and arrangement carefully before putting up a plant. Although it is impossible to enter into a thorough discussion of the subject in this bulletin or to lay down hard



FIGURE 1.—A good stand of sorgo just before harvesting.

and fast rules, a few important points should be kept in mind. The plant should be easily accessible to those bringing in the crop and the fuel, and should have adequate means for storing and taking care of the finished product. It should also be near an abundant supply of water, so that all the equipment may be washed as often as necessary. The importance of cleanliness in making sirup cannot be too strongly stressed. As one object of skimming and evaporation is the removal of suspended material and the sterilization of the sirup by heat, it is obviously unreasonable to permit dirt of any kind to contaminate the sirup after it has been made. All equipment that has stood idle for several days may be thoroughly washed with strong lime water, which neutralizes acids and to a certain extent prevents fermentation. If lime is used, however, all equipment should be carefully washed again before resuming operations, as the addition of excessive lime to juice or sirup is injurious. In addition to keeping the evaporator and tanks free from sediment and scale, it is well to dispose of the skimmings in such a way that they do not create an unsanitary condition around the mill. Screens and covers should be used as freely as practical to protect the sirup from dust and insects.

In a small plant it is not necessary to cover all the equipment, although some roofing and screening are desirable.

HILLSIDE LAY-OUT

A hillside location is best for small plants. The mill should be placed on the highest level, the raw juice should run into tanks below, and the evaporator should be placed still lower. This arrangement takes advantage of gravity, making it unnecessary to carry the juice from place to place. The evaporators also should have sufficient

elevation to insure convenient handling of both the semisirup and the finished product. This plan can be carried out with mills of different sizes, including power mills. The hillside layout is shown in figure 2.

Placing the mill shed some distance from the evaporator diminishes the noise nuisance from the gasoline engine. Elevating the base of the mill 4 or 5 feet above the top of the evaporator makes it possible to bring the juice from the mill to the evaporator by gravity and makes

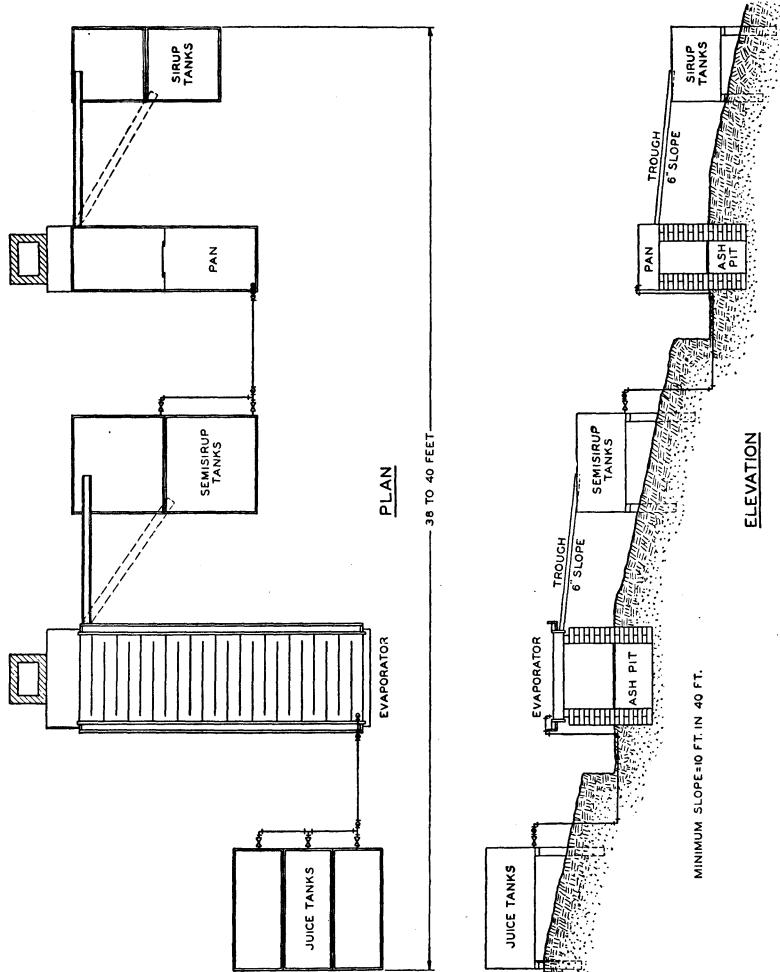


FIGURE 2.—Hillside lay-out of a sorgo sirup plant.

prompt removal of the bagasse unnecessary. A platform 12 feet square and 4 feet high, made of heavy material, provides space for a good supply of stalks, and, if covered, affords shelter during bad weather for the man who feeds the mill.

Owing to the fact that the weather is usually warm when sorgo sirup is made, the evaporator as a rule is kept in the open, except for a suitable roof. Movable shields may be used to prevent the wind from blowing too strongly on the pan. Too much wind retards evaporation

and makes for inefficient as well as unpleasant working conditions. Walling up the house or shed for the evaporator or the use of movable shields causes vapors from the pan to rise and escape through the ventilator, thus interfering as little as possible with the work of the sirup maker. A partition in the pan house is desirable because it

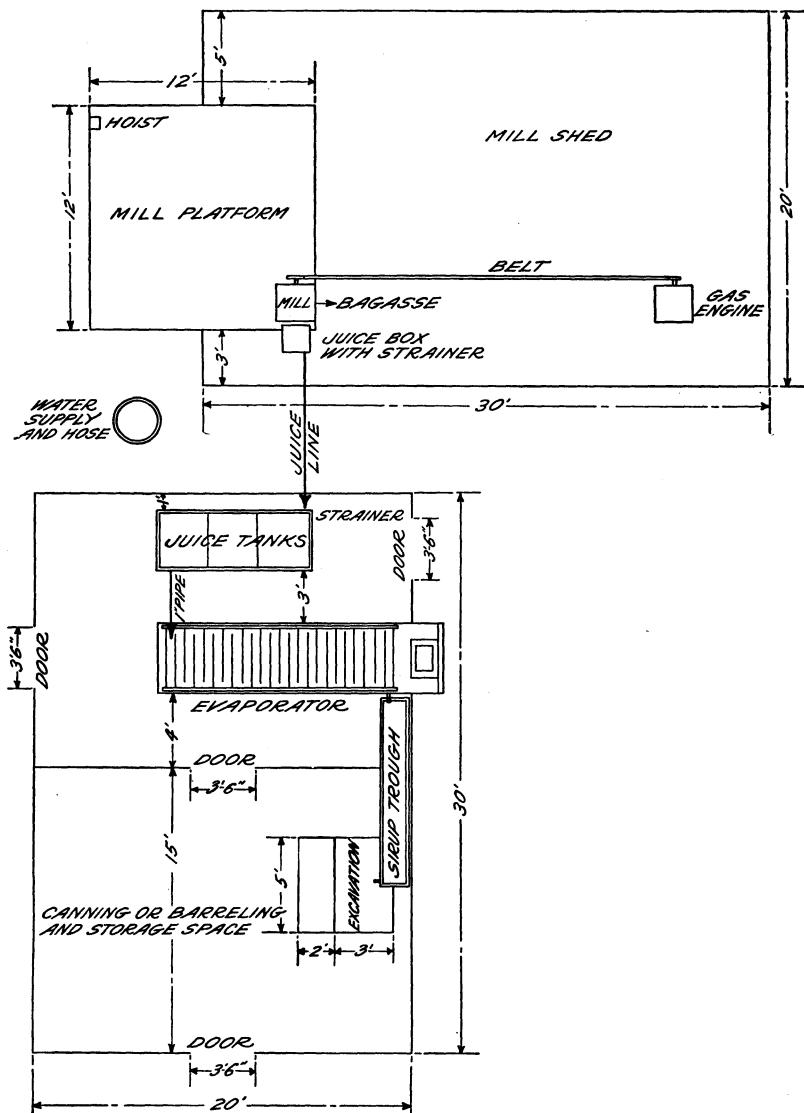


FIGURE 3.—Plan of sirup plant when only one evaporator is used.

keeps escaping vapors from coming in contact with the cans in the canning room. Such vapors cause the cans to rust very quickly. The storage room should also be as dry as possible for sanitary reasons.

If possible, the ground around the evaporator should be hard-surfaced and sloped enough to furnish drainage. The arrangement

and equipment should be such that sirup making can be done efficiently and under sanitary conditions.

Use of a large juice tank partitioned into three compartments, or of three separate tanks, makes it possible for each tank of juice to settle for 2 hours before being drawn into the evaporator. While the juice is settling in one tank, the evaporator is being supplied with a previously settled lot, and juice from the mill is running into the third tank. Care in removing as much as possible of the impurities of the cold juice by settling before running it into the evaporator will be well repaid by the improved quality of the sirup. A large part of the starch settles out of sorgo juice (pp. 29-31).

Pipe connections should be not less than three-fourths of an inch in diameter, and they should be equipped with gate valves. The pipe to the evaporator may be a vertical U, partly buried under the ground instead of passing directly across to the evaporator; this gives an unobstructed passage around the pan. The discharge end of each tank is slightly lower than the other end, so that it may be com-

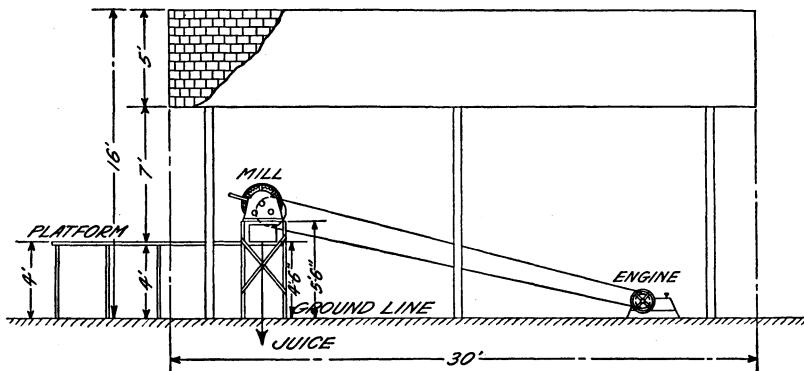


FIGURE 4.—Side elevation of mill shed.

pletely drained. A second opening, fitted with a valve or plug, is used for draining and washing. Thin covers or screens to fit the tanks will assist in keeping out insects and trash.

This method of milling and handling juice is applicable regardless of the equipment used for evaporation.

Figure 3 shows a convenient arrangement for a power mill with an 8-horsepower engine and a 12-foot evaporator when only one evaporator is used. The side elevation of the mill shed and the sectional side elevation of the pan (evaporator) house for the same arrangement, when on level ground, are shown in figures 4 and 5. It is inconvenient and comparatively expensive to shelter a horse-driven mill, on account of the space required for the sweep.

The juice flows from the mill through a coarse four-mesh screen into a small juice box, one with a capacity of 4 cubic feet being large enough (fig. 3). A 1½-inch pipe carries the juice from this box to juice-settling tanks in the pan house near the evaporator. This arrangement reduces the contamination of the juice by mill trash and provides a better opportunity for straining the juice through a sack or screen. Three juice-settling tanks, each large enough to hold a 2-hour juice supply from the mill, are provided for settling the cold

juice. These also permit continuous operation of the evaporator, if it is necessary to stop the mill. Juice entering the settling tanks is strained through a coarse sack suspended in the tanks, or through a wire screen, to remove crushed leaves, seed, and particles of soil, bagasse, etc.

SIZE OF MILL, ENGINE, AND EVAPORATOR

The small size of individual plantings of sorgo and the fact that the total tonnage produced in a given locality is not always centralized enough to permit efficient operation of a large plant frequently make

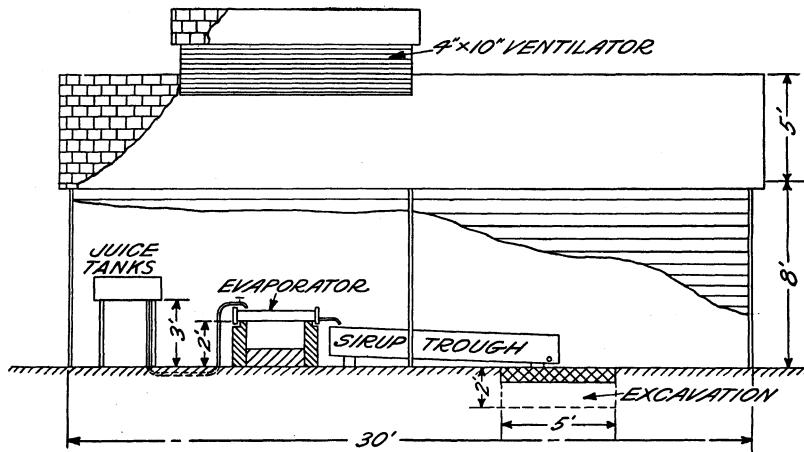


FIGURE 5.—Sectional side elevation of pan house when on level ground.

it more desirable for farmers to make the sirup on a comparatively small scale. This reasoning applies both to individual and to custom plants. The capacity of mill, engine, and evaporator should be so chosen as to permit economical and steady operation. The sirup-making season usually lasts only 5 or 6 weeks, during which period a horse-driven mill, with a small evaporator, can handle a season's output ranging from 1,500 to 2,500 gallons of sirup. A power mill, with a larger evaporator steadily operated, is adequate for a 10,000-gallon output. Table 5 may be of assistance in selecting mills, engines, and evaporators of appropriate capacity.

TABLE 5.—Equipment for small-scale sirup making

Capacity of mill in tons of sorgo per 12-hour day	Power	Length of evaporator	Capacity of mill in tons of sorgo per 12-hour day	Power	Length of evaporator
3 to 5	Horsepower 1 1 1 2 6 to 8	Feet 2 7.5 3 10.5 12	12 to 15	Horsepower 10 15	15 12
6 to 8			16 to 20		
9 to 11					

¹ Horse- or mule-operated.

² Or a 60-gallon kettle.

³ Or a 100-gallon kettle.

⁴ Two 12-foot evaporators.

EXTRACTING THE JUICE

The juice is obtained from sorgo by milling, that is, running the stalks between the iron rollers of a mill. Mills may be obtained with

upright or horizontal rolls. The smaller mills (figs. 6 and 7) are operated by horses or mules; the larger ones (fig. 8) are operated by power. Mills with grooved rolls are easier to feed, and in such mills the stalks tend less to twist to one side.

A good mill is one that can be taken apart easily and new pieces substituted when breaks occur. It must run smoothly and true for good results. The rolls must be capable of adjustment. In setting up such mills, care should be taken to have the mill level and rigid on the frame or upright supports, which should be carefully braced. Without these precautions, imperfect pressing will result and perhaps a break in the mill. Power mills (fig. 8) are either single- or double-gearred, so they can be connected with a farm engine or electric motor. A feed table is an important addition to a milling outfit, especially for

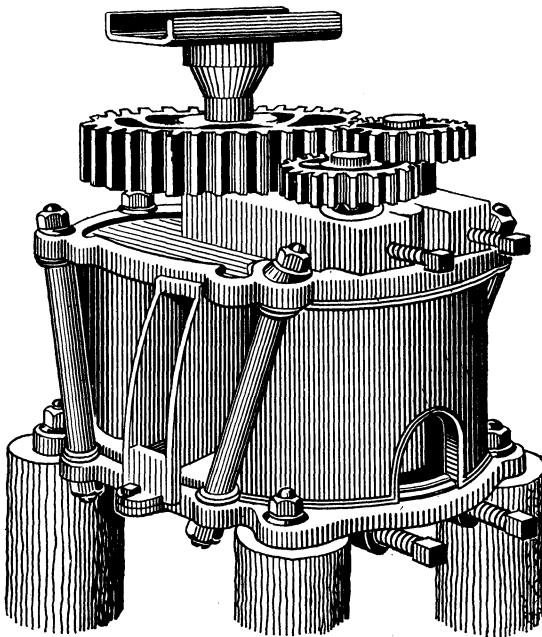


FIGURE 6.—Three-roller vertical horsepower mill.

a power mill, as it allows the stalks to be arranged in some order before entering the rolls, thereby providing a more even feed.

Careful adjustment before starting is necessary in small power mills to obtain good extraction and avoid loss and delay from the breaking of parts. Setting the small front roll too close to the large roll prevents the mill from taking the stalks readily. A clearance space of approximately three-eighths of an inch between the front roll and the large roll permits the sorgo to enter the mill promptly and keeps it from being cut up before it reaches the last roll. The clearance space between the last small roll and the large roll should be about one-sixteenth of an inch. With this setting of a three-roller power mill and full-capacity feed, the stalks are squeezed fairly dry. The speed of the mill should be regulated according to the recommendation of the manufacturer; it is usually about 27 feet per minute for the large roll, which is equivalent to 10 to 12 revolutions per minute for the

average small power mill. As the size of the mill increases, the number of revolutions per minute should decrease. The engine speed for the types commonly used ranges from 375 to 425 revolutions per minute.

The "feed", or quantity of stalks in the mill at one time, should be light or heavy according to the adjustment of the rolls. When they are set "open", or apart, the feed should be heavy; when they are set close together the feed should be light. In all cases it should be regular and uniform. It is evident that with open-set rolls juice is wasted when the feed is light; with close-set rolls there is also a loss of juice when the feed is irregular and uneven.

Sorgo ordinarily contains over 70 percent of water and 10 to 15 percent of fiber, but it is impossible to obtain all the water as juice.

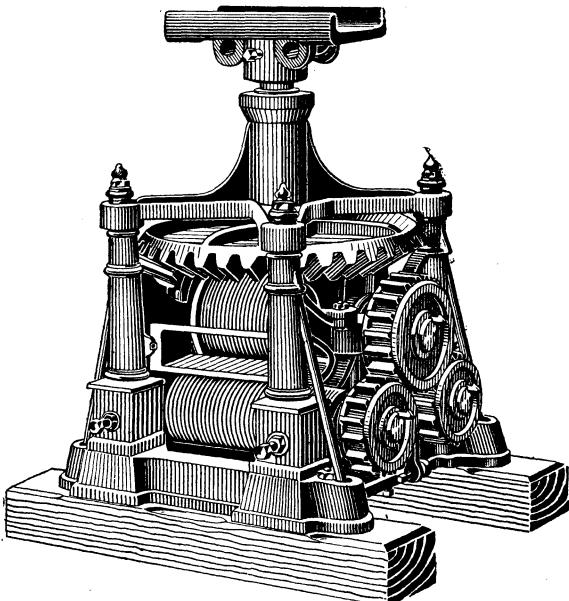


FIGURE 7.—Three-roller horizontal horsepower mill.

With a three-roller power mill, the weight of the juice extracted should be 50 to 60 percent of the weight of the stalks, unless they are very hard and dry. With a good mill and close setting, 60-percent extraction is not too much to expect from the best varieties of sorgo, if it has been a season of normal rainfall and if the stalks have not dried out too much between harvesting and milling.

Although the percentage of total solids is not identical with the number of degrees indicated on the Brix hydrometer scale, the solids content of the juice may conveniently be expressed in terms of this scale. With good sorgo this is usually 14° to 18° Brix, that is, the juice has approximately 14 to 18 percent of dissolved solids, the remaining 82 to 86 percent being water. When the apparent solids content, or degrees Brix, of such juice is expressed in terms of the Baumé hydrometer, it is said to have a "density" of 7.9° to 10.1° Baumé. The degrees of the Baumé scale do not correspond even approximately

to the percentage of apparent solids; for all practical purposes in testing sorgo juice, Baumé degrees $\times 1.78$ equals Brix degrees.

Assuming an extraction of 60 percent, that is, 60 pounds of juice per 100 pounds of stalks, and an average Brix reading of 15° for the juice, the juice from 100 pounds of sorgo, if evaporated to a sirup of 76° Brix without losing any of the dissolved solids, should yield $15/76 \times 60$ pounds, or 11.84 pounds, of sirup. A United States gallon of sirup at 76° Brix weighs 11.57 pounds; hence, the 11.84 pounds of sirup is equivalent to 1.02 gallons. This represents the theoretical yield in gallons of sirup from 100 pounds of sorgo. Theoretically, therefore, a ton of stalks yields 20.4 gallons of sirup. The actual yield of sirup

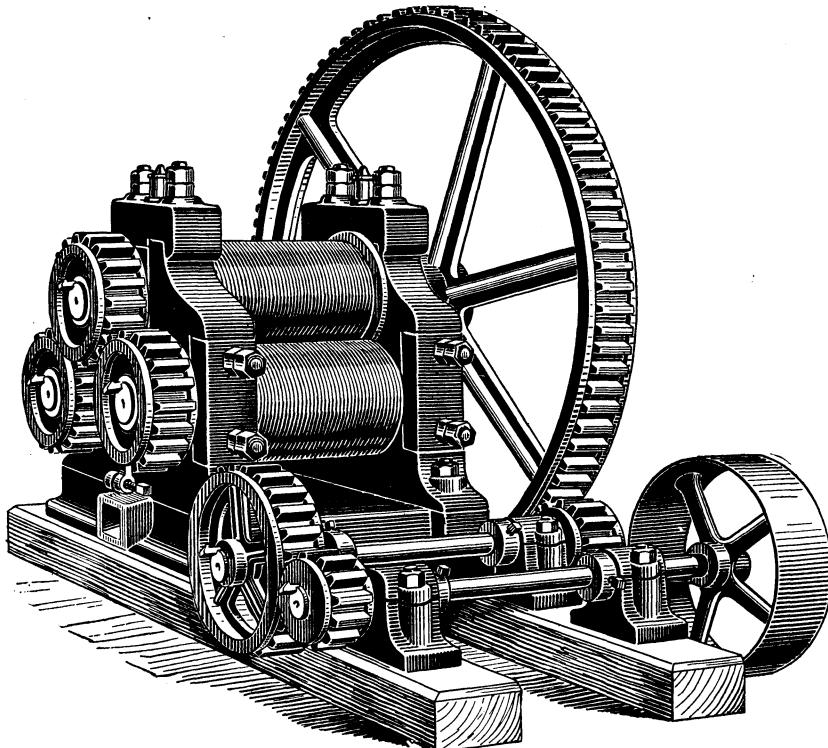


FIGURE 8.—Three-roller power mill.

per ton, however, with 60-percent extraction and with juice testing 15° Brix, is only 17 to 18 full United States gallons. (No. 10 cans do not hold a full United States gallon of sirup.) Not all the dissolved solids in the juice are retained in the sirup, and some juice is unavoidably lost by skimming, settling and decanting, and straining. This loss is especially great in small farm outfits. The actual yield of sirup, therefore, is 12 to 18 percent below the calculated theoretical yield.

With smaller mills, driven by horsepower or even by gasoline or kerosene engines, and with sorgo of poor quality, the extraction is frequently as low as 50 percent, or lower, instead of the 60 percent assumed for the larger three-roller mills and good sorgo. Moreover, early in the harvesting season, when the crop may be less mature, the juice may test less than 15° Brix or even less than 14° . In such cases,

the yield of sirup is proportionately reduced. When unusually low extraction is being obtained by use of a small mill, it may be practicable to gather up the bagasse ("pomace" or "chews") and put it through the mill again. Oftentimes half again as much juice can be obtained by "double passing" as results from putting the stalks through only once.

MAKING SIRUP ON SHARES

Farmers may often grow sorgo without caring to manufacture it into sirup themselves. Upon what basis should the sirup be made by a custom mill? One of two general methods is usually followed. The maker charges the farmer a stated price per gallon or he makes it on shares, that is, he gives the farmer a certain percentage of the sirup produced.

When sirup is being made on shares, the following method may be used to avoid boiling the juice from each lot separately. The material is ground separately, and the juice from each lot is collected in tanks where it can be measured. From the quantity of juice and its Baumé reading, the quantity of sirup that will be made may be calculated with a fair degree of accuracy.

The settling tanks are convenient for measuring the raw juice. If the tank is rectangular, take the inside dimensions, length and width, in inches, multiply these and divide the result by 231 (the number of cubic inches in a gallon) to obtain the gallons of juice in the tank for each inch of depth. The number of inches of juice may be determined by inserting a stick or rule in the tank, and this figure, multiplied by the gallons per inch of depth, gives the number of gallons of raw juice.

If the measuring tank is round, multiply the diameter, in inches, by the diameter, in inches (identical figures). Multiply this result by 0.7854 and divide the result by 231. The figure thus obtained shows the number of gallons of juice in the tank for each inch of depth.

The other figure necessary for the calculation is the density of the juice as determined by means of a Baumé hydrometer. This instrument is preferably suspended in a cylinder of juice (fig. 9), but it can be placed in the tank, provided the juice is deep enough to allow it to float freely. From the volume and Baumé reading, the yield can be calculated. The density of the raw juice will be determined more accurately if the reading is not made for at least 30 minutes, or until most of the air in the juice has escaped. In one typical case, 10 gallons of juice with a reading of 6° Baumé made 1 gallon of finished sirup. From these and similar data the following sliding scale was calculated for use with that particular sirup maker's equipment.

° Baumé of juice:	Gallons of juice per gallon of sirup	° Baumé of juice—Con.	Gallons of juice per gallon of sirup
6-----	10	8½-----	7
6½-----	9	9-----	6½
7-----	8½	10-----	6
7½-----	8	11-----	5½
8-----	7½	12-----	5

The number of gallons of juice multiplied by the Baumé reading gives approximately 60 in every case. Each sirup maker can, and should, prepare for himself such a table, as his method of manufacture may not be like the one used here. To do this, it is necessary to obtain the Baumé reading of several tanks of juice, then concentrate

the juice to sirup in the usual way, and measure the finished sirup. Multiplying the Baumé reading of the juice by the number of gallons of raw juice and dividing by the number of gallons of finished sirup made gives the figure on which to base the table. (The figure happened to be 60 in the example given.) With this beginning, a table can be prepared for different Baumé readings on the raw juice. In this way, as soon as a separate lot of sorgo is ground, the juice can be measured, the density determined, and the quantity of sirup due the grower calculated without interfering with the continuous work of the evaporator.

At some custom mills where settling and treating tanks are used for the semisirup, the operators prefer to measure these tanks and

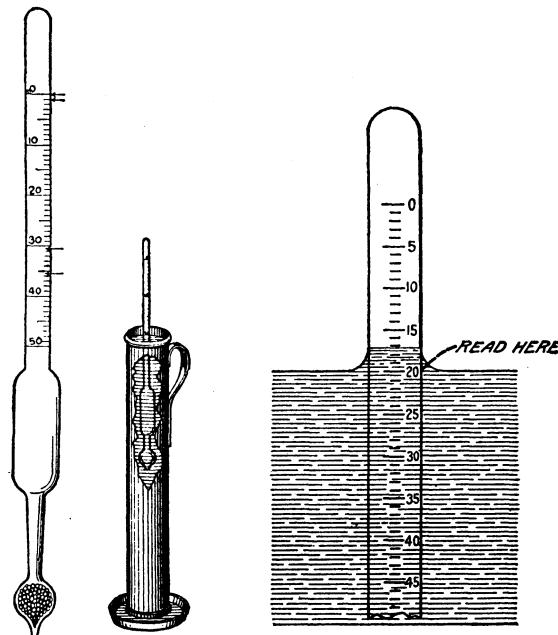


FIGURE 9.—Hydrometer suspended in a cylinder of juice. Note the point on the scale at which the reading should be made.

gage the semisirup from each individual's lot of sorgo, rather than use the above method of gaging the juice. After a little practice in observing the rate at which the juice from different lots of sorgo is evaporated and semisirup is made, the sirup maker may gage the semisirup with a reasonable degree of accuracy. The yield of sirup is very nearly one-half the volume of 20° Baumé semisirup.

TREATING THE JUICE

In making sirup, 1 gallon of sirup is usually obtained from 6 to 7 gallons of juice, 5 to 6 gallons of water being evaporated. Sorgo juice, however, contains many substances besides sugar and water. As first obtained at the mill, the juice contains some suspended soil, which has adhered to the stalks, particles of finely ground stalk or fiber in suspension, starch, and certain dissolved substances. Among

the dissolved nonsugar substances, which are commonly classed as impurities because they represent material other than sugar but which are just as much a part of the juice as is the dissolved sugar itself, are organic and inorganic salts, proteins, pigments, starch, gums, and wax. These so-called impurities affect the quality of the sirup, but not all of them are objectionable. Although it is never necessary or feasible to remove all of them, some must be eliminated to make a sirup of satisfactory flavor, color, and clarity. In small-scale practice, the manufacture of sirup consists in the evaporation of excess water and the removal of certain impurities by straining, skimming, and settling.

Raw sorgo juice coming from the mill should first be well strained and then settled for 2 hours while still cold before it is run into the evaporator. This settling of the cold juice is especially important in removing a part of the starch. The draw-off line from the settling tanks or barrels should be 1 to 2 inches from the bottom to avoid drawing the sediment into the evaporator. Separate wash-out openings should be provided in the bottom of the tanks or barrels so that these may be easily washed out before more juice is run into them (p. 10). The settling may be combined with the skimmings and used for feeding livestock (p. 39).

The addition of chemicals to the juice throws out certain impurities but generally leaves in their place part of the foreign substances added, and very often completely changes the flavor of the resulting sirup. As a rule, the small producer of sirup should not attempt to employ chemical methods of clarification. Even on a larger scale great care must be used in adding chemicals, as a slight excess of some of the substances used may ruin the color and flavor of the sirup.

Some of the treatments occasionally used for clarifying the juice are described below.

PHOSPHORIC ACID COMPOUNDS

In treating sorgo juice with phosphoric acid compounds, two methods have been used. In one, the phosphoric acid is added to the raw juice, which is then limed before heating. In the other, lime is added until the juice becomes alkaline, then phosphoric acid is added until it is slightly acid. The juice is then heated. These procedures greatly change the flavor of the resulting sirup, and their value is very questionable.

LIME CARBONATE (WHITING)

Ordinary hydrated lime is strongly caustic, but whiting, or carbonate of lime, is not. When using this material, heat the juice and stir it vigorously while the whiting is being added. Much more whiting than lime is required, and a slight excess usually does no harm, although care must be taken to leave the juice sufficiently acid. If too much whiting has been used, the proper acid reaction may usually be regained by adding fresh raw juice.

As an alternative, carbonate of lime may be used at the semisirup stage of evaporation. It is "boiled in" for a few minutes before the semisirup is removed from the evaporator to the settling and treating tanks. Some of the acid is removed by the evaporation of juice to semisirup, so that less carbonate of lime is required for treating the semisirup. If an excess is used, it settles out overnight. This method is likely to give sirup of better quality.

MILK OF LIME

Although it is not usually needed with sorgo of good quality, especially when properly topped (table 4), a small amount of milk of lime is sometimes used to modify the acid flavor or "tang" of sorgo sirup. In certain localities, especially where sorgo has replaced sugar-cane, or where both kinds of sirup are made, the characteristic tang of sorgo sirup may be disliked. The people of such localities usually prefer a mild-flavored sirup. The use of lime in the proper manner tends to give a milder flavored sirup, as also does the use of malt extract (pp. 19, 31).

The lime should be used very carefully, because too much of it may give a sirup of dark color and remove too much of the characteristic sorgo flavor. Ordinary hydrated lime is mixed with water to make a thin milk (about 1 pound of hydrated lime per gallon of water) and some of this is stirred, little by little, into one-third of a tank or barrel of the cold juice from the mill. After each addition the juice is tested with bromthymol blue test paper. The addition of lime is not continued until the juice turns the test paper deep blue; it is stopped as soon as the test paper turns green. The third of a barrel or tank of juice thus treated is purposely overlimed, so the remaining two-thirds of the barrel or tank is filled with fresh juice from the mill without the addition of more lime. After mixing, the full barrel or tank of juice will possess the proper degree of acidity. The juice must be left slightly acid to make the best-quality sirup.

Litmus papers may also be used for controlling the addition of the lime. When using litmus instead of bromthymol blue papers, it is again the best plan to add the lime to one-third of a barrel or tank of the cold juice. The lime is added little by little, with stirring, until blue litmus paper does not turn red when dipped into the juice, or until red litmus paper first turns blue. In other words, no more lime is added after the acidity of the juice is barely neutralized. The third of a barrel or tank of juice thus treated is purposely overlimed, so the remaining two-thirds of the barrel or tank is filled with fresh juice from the mill, without adding any more lime. After mixing, the full barrel or tank of juice will possess the proper degree of acidity.

Litmus paper can be obtained from the local drug store in small vials or in sheets. Either the blue or the red litmus is satisfactory. If sheet litmus is used, a piece should be cut for immediate use, clipped into small pieces, and put into a small bottle, which may be corked and carried in the pocket. The rest of the sheet should be put away in a corked bottle for future use. Acid vapors in the air and fingers moist with acid juices redden and spoil blue litmus paper, and a little lime spoils the red litmus. By moistening the tip of the finger and touching one of the pieces of the litmus paper, it may be picked up without handling the others.

A less accurate method of adding lime can also be used. With practice, this gives fairly good results. For determining when the correct amount of lime has been added to one-third portions of the juice, as above described, the juice is tasted after each addition, and when it becomes dead sweet to the taste no more lime is added. At this stage the juice loses its characteristic sorgo tang. Moreover, the juice at this point is not light green but is either brown or dark green. The fresh juice is then added from the mill.

MALT EXTRACT

Certain types of malt extract of high diastatic power, and other commercial diastase preparations, give good results in remedying slow boiling and scorching and in preventing sorgo sirup from clabbering or jelling. The malt extract is added, with thorough mixing, to the cold juice in barrels or tanks at the mill at the rate of one-fourth to one-half pound to a barrel of juice (50 gallons). In treating juice of extremely poor quality it may be necessary to double the proportion of the malt extract. If desired, the cold juice may be treated also with a small amount of milk of lime (p. 18). The juice is allowed to stand for 2 hours. It is then run into the evaporator as usual, care being taken not to stir up the sediment in the bottom of the barrel or tank. The draw-off lines from the barrels or tanks should be 1 to 2 inches from the bottom, and the tanks should slope about 1 inch toward the draw-off valve. The malt extract does not detract from the value of the settlings and skimmings for feeding purposes, etc. The evaporation of the juice to finished sirup is conducted in the usual manner.

By providing three storage tanks for holding juice at the mill (p. 10), it is possible to arrange easily for continuous operation. The cost for malt extract is only about one-half cent to 1 cent per gallon of finished sirup. Sorgo sirup produced in this way is of lighter color and milder flavor, and the sirup can be made to have the proper density. (For the method of using malt extract on the semisirup, which is preferred to the juice method, see p. 31).

EVAPORATING THE JUICE

Although the quality of sirup depends to a very large extent upon the variety of sorgo, the type of soil on which the crop is grown, the fertilizer used, and the kind of growing season, it may also be greatly influenced by the equipment and process used in manufacture and by the skill of the sirup maker.

When heat is applied to the juice much of the starch is made soluble, but certain proteins and other nonsugar substances become coagulated. If allowed to settle, some of this coagulated material rises to the surface of the juice and some sinks to the bottom. By the most approved practice, this material is removed as quickly as possible by skimming as soon as it appears on the surface of the juice. Success in making sirup depends first of all on the thoroughness with which the juice is skimmed before it begins to boil rapidly. The agitation of the juice due to active boiling breaks the coagulated material into smaller particles, which are more difficult to remove by skimming than the original mass. This breaking up of coagulated material is commonly referred to by sirup makers as "boiling-in" the impurities. Additional nonsugar substances separate as boiling continues and the juice becomes denser, making it advisable to continue the skimming until the juice has been evaporated to the density of finished sirup, even though careful skimming has been done at the beginning of the evaporation.

KETTLES

Of the many types of equipment used for concentrating juice to sirup, kettles are probably the oldest, and a product of fair quality results when they are properly operated.

The advantages in using kettles for small-scale sirup making are:

- (1) The density of the finished sirup may be readily controlled;
- (2)

the method requires but little skill; (3) a long period is available for skimming, thus making it possible to obtain a clean sirup. The disadvantages are: (1) A long period is required for evaporation, frequently $3\frac{1}{2}$ hours or longer; (2) a dark product may be obtained as a result of the prolonged slow boiling; and (3) it is feasible only on a small scale, when a single kettle is used.

The flame must not be allowed to rise above the level of the boiling juice in a kettle; otherwise the sirup will burn and have a scorched taste. Another precaution necessary when making sirup in this kind of apparatus is to concentrate a single charge. Adding fresh juice to the boiling sirup always results in a dark-colored sirup, with poor flavor and clarity. After a charge has been concentrated, the kettle should be swung from the fire, the sirup poured out, and the sediment washed out before it has had time to burn. If the kettle cannot be removed from the fire, after two or three charges remove the fire and clean the kettle.

BATCH PANS

Instead of kettles, batch pans about 8 to 10 inches deep made of copper, galvanized iron, heavy tin, or sheet iron are used by many sirup makers. A single pan may cover the whole space occupied by the furnace, or two or three pans may be used, one back of the other. These may or may not be connected so that the juice can flow from one to another. Some prefer a home-made pan constructed of $1\frac{1}{2}$ -inch lumber, with a bottom of copper, galvanized iron, or sheet iron carefully luted to the sides. If properly operated, this type of pan gives good results.

STUBBS PAN

The Stubbs pan, sometimes known as the Louisiana-type evaporator (fig. 10), is continuous. Although not so widely used as the well-known, shallow, baffle-type, continuous evaporator, it possesses the following advantages: (1) It requires somewhat less skill for efficient operation; (2) when this pan is properly operated and the furnace construction is good, the skimmings collect automatically on the cool juice surface; (3) only a slightly deeper layer of juice is maintained in this pan than that carried on a shallow, baffle-type evaporator; (4) the high partition separating the finishing-off compartment from the rest of the pan makes it possible to regulate more efficiently the evaporation of semisirup to the density of finished sirup in controlled batches without danger of flooding or admitting improperly skimmed semisirup; (5) the density of the sirup can be more easily controlled than by the use of the more shallow evaporator; (6) sirup of excellent quality can be made on this type evaporator; and (7) this is a type of continuous evaporator that may be constructed on the farm.

Figure 10 shows the design of the Stubbs pan. The juice enters continuously at (a), travels down the pan lengthwise on the juice side of the high, longitudinal partition, around the end of this partition, and then toward the finishing-off compartment at the chimney end. The finishing-off compartment should be provided with a tight-fitting, easily workable gate to admit batches of semisirup as desired. The design of the furnace for this evaporator is similar to that for the shallow evaporator, with the exception that the chimney is built to one side, next to the finishing-off compartment, and the fire is prevented from striking against the corner of the pan where the raw juice enters, either by use of a damper or by building a solid perpendicular

wall across this corner of the furnace. This transverse wall, or solidly filled-in corner of the furnace, helps to keep the juice from boiling at the raw-juice end of the pan, the result being a relatively cool juice surface on which the skimmings collect and can be removed without danger of boiling-in. The arch of the furnace is so constructed that

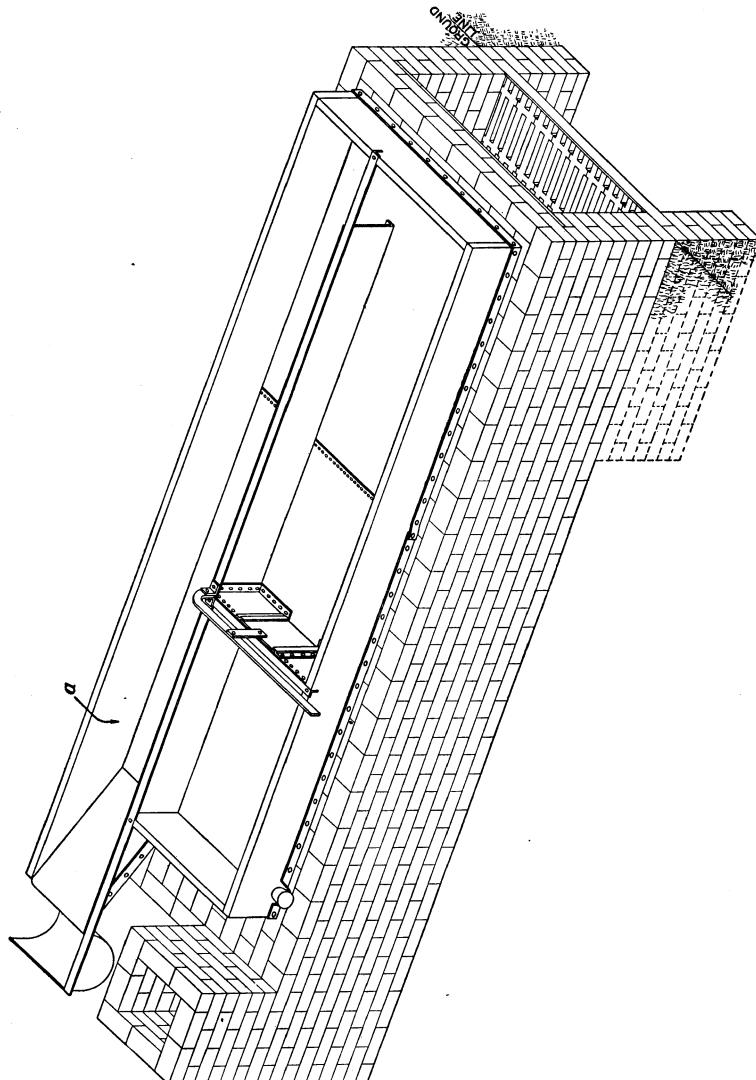


FIGURE 10.—Stubbs-type evaporator. This model is 12 feet long, 3 feet 6 inches wide, and 10 inches deep. The juice side (a) is 15 inches wide, whereas the other side is 2 feet 3 inches wide.

the highest point is about $1\frac{1}{2}$ feet beyond the center of the pan toward the sirup end. As this is the part of the pan, on the sirup side, where the juice is being concentrated to semisirup density, and as the heat is closest underneath, the surface of the boiling juice stands higher in the pan at this point. The height of the foam gradually diminishes toward the end over the firebox and from there to the cool raw-juice corner. In other words, the foam, carrying the skimmings with it,

cascades down around the end of the longitudinal center partition of the pan and flows back on to the incoming raw juice surface, which is not boiling at all. This type of pan, therefore, does not require skimming troughs, although the skimmings automatically collect in somewhat the same fashion in just one part of the pan, where they may be more easily removed.

EVAPORATORS

Continuous evaporators, sometimes called patent evaporators, have many points of superiority to recommend them. The bottoms are sometimes corrugated to give a larger heating surface, and an automatic supply valve may be used to regulate the depth of the liquid in the evaporator. They are constructed in such a way as to produce a quick concentration of the juice to sirup, and with proper operation, to facilitate efficient skimming.

Most of the sorgo sirup made by farmers operating on a relatively small scale is made on open, galvanized-iron or copper evaporators. These evaporators are shallow and have crosswise baffles. A galvanized-iron evaporator is cheaper than one of copper; with proper care it will last a reasonable length of time, and while new, will produce sirup of as good quality as can be made in the copper evaporator. Sorgo juice, however, is always slightly acid and consequently gradually corrodes galvanized iron. When the zinc surface of the galvanized iron becomes corroded and pitted, the juice is boiled in contact with the exposed iron, which reacts with certain constituents of the juice to produce a dark sirup. Although a copper evaporator costs nearly twice as much as one of galvanized iron, the extra expense is more than counterbalanced by the advantages gained. Copper lasts much longer than galvanized iron; it can be easily cleaned, without injury, by the use of acid, while the galvanized iron cannot; it conducts heat better than does galvanized iron; and the use of a copper evaporator results in a lighter colored sirup. The first cost of a good evaporator is only a small item in the total cost of making sirup, so the use of copper is in no sense of the word an extravagance.

The advantages of continuous-type evaporators are: (1) Rapid evaporation, which is essential in making light-colored sirup, is obtained; (2) the sirup is concentrated in a thin layer, thus increasing the rate of boiling and foaming and affording better opportunity for thorough skimming; and (3) heat is applied to the bottom of the evaporator, thus imparting an upward motion to the coagulated material, whereby skimming is facilitated. The disadvantages are: (1) More attention is required to maintain a properly regulated flow of juice; (2) there is increased danger of scorching the sirup and altering its color and flavor; (3) more careful attention to firing is necessary; and (4) it requires more skill to obtain uniform sirup density.

In continuous evaporation, a steady stream of juice flows by gravity into the lower end of the pan and then flows slowly to the opposite end, at which point it reaches the density of sirup. The juice end of the pan is sufficiently lower than the finishing end to maintain a juice layer from 2 to $2\frac{1}{2}$ inches deep, which should give a layer three-fourths to $1\frac{1}{2}$ inches deep (preferably only three-fourths inch) in the finishing end of the evaporator. In other words, the juice end of the evaporator is mounted on the furnace about 1 inch lower than the sirup end. The evaporator should be level from side to side. As a rule, the juice

enters the front end of the pan and during evaporation moves toward the back or chimney end. In some instances, however, the juice enters at the chimney end and is drawn off as sirup at the front end. During evaporation to sirup, the juice, with continuous skimming, flows toward the finishing end of the evaporator, while cold juice from the supply tank is run in to maintain the desired level in the juice end of the pan. The heat applied to the juice from the bottom of the pan increases from the juice end to that part of the evaporator where there is danger of scorching the sirup. Beyond this point, the heat applied gradually decreases, until only a small amount is required under the last compartment, from which the sirup is drawn off. The hottest portion of the pan, and consequently the place where the juice boils most vigorously, is where concentration to sirup is a little more than half completed. This scheme of operating a continuous evaporator makes it easier to regulate the boiling and skimming. The scum is carried back to the juice end of the pan with the foam and may be readily removed by skimming.

FURNACE FOR EVAPORATOR

The furnace for a continuous evaporator must be properly constructed, and the fire must be carefully controlled. In direct-fire evaporation, success depends to a great extent upon the construction and operation of the furnace. The capacity of a plant equipped with a mill and evaporator of the best type may be reduced as much as 50 percent by an improperly constructed firebox and ashpit. The quality of the sirup may also suffer greatly because of improper skimming and slow evaporation, both of which are caused by poor furnace construction. The distribution of heat over the bottom of the pan is controlled by filling in the furnace between the end of the grates and the chimney. Although all furnaces look very much alike on the outside, they differ greatly in the size of firebox, ashpit, chimney, and filling.

Figure 11 shows a 12-foot evaporator and suitable furnace. With good sorgo and a power mill, the capacity of this equipment is 100 to 150 gallons of sirup per 12-hour day. The dimensions for width, height, distance of grates below pan, and thickness of wall apply also to furnaces for evaporators of other lengths. For longer furnaces the length of the firebox should be increased to 4 or $4\frac{1}{2}$ feet. The chimney of the furnace should be at least as high as the furnace is long. Sometimes it works better if it is one and one-half to two times as high. This depends upon the burning quality of the wood. A well-constructed firebox is about $2\frac{1}{2}$ inches longer than the wood used. The highest point in the filling of the furnace, where the flames are brought closest to the pan, should be approximately $1\frac{1}{2}$ feet beyond the middle of the evaporator toward the sirup end.

Some furnace fronts manufactured with grates attached provide too small a firebox. Moreover, if the fronts are heavy, the continual opening and closing of the door frequently tears the end brick from the furnace. Sirup makers often install a grate in the proper position, using for the front a large piece of sheet metal hung from a joist of the pan shed. This inexpensive arrangement works very satisfactorily, affording a larger door for firing and rapidity in opening and closing. The firebox should by all means be provided with a door of

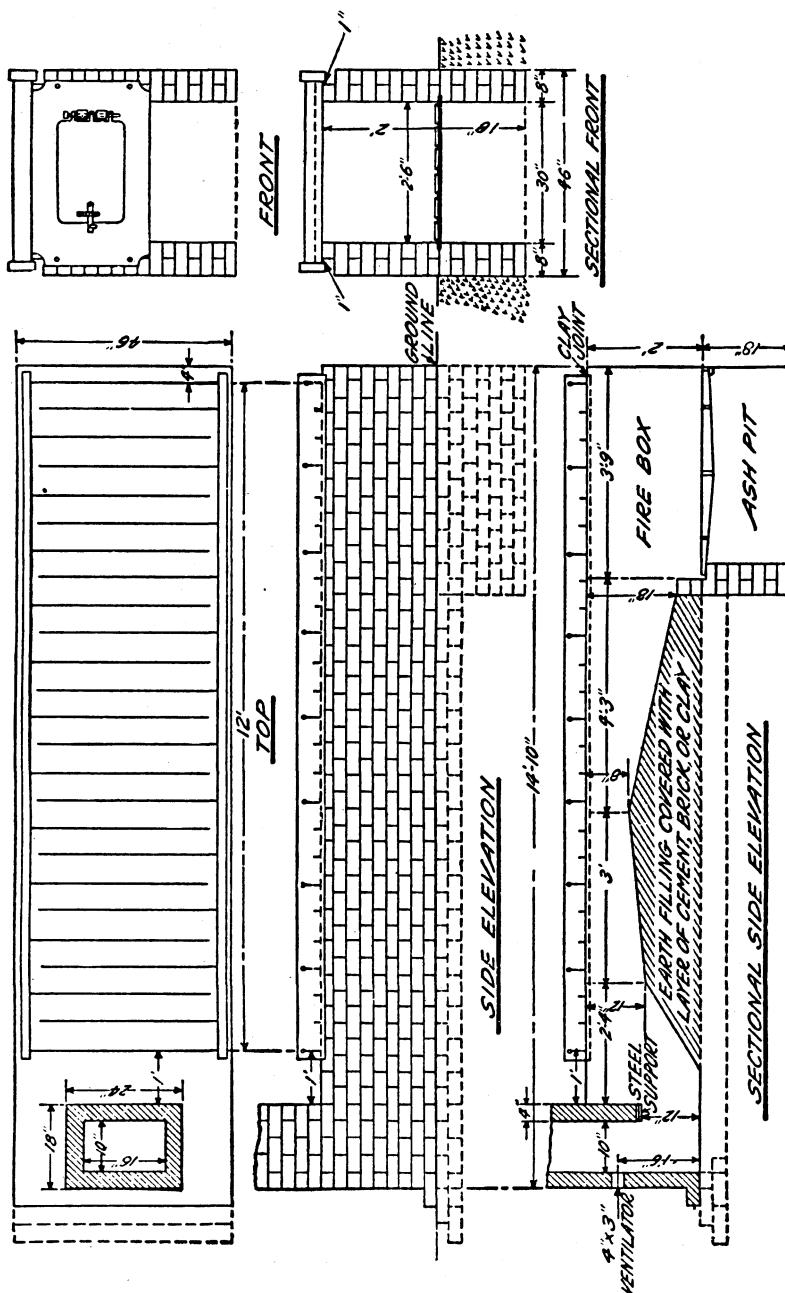


FIGURE 11.—A 12-foot continuous evaporator and furnace.

some sort. The furnace should be so located that the front end faces prevailing winds, and the ashpit should be reasonably deep to permit free access of air to the firebox from beneath. Some sirup makers keep the ashpit partly filled with water to prevent the accumulation of excessive heat under the cold-juice section of the evaporator.

Beginning at the bottom of the ashpit, a transverse double-thick brick wall is built up to the bottom of the grates and furnishes a support for their back end. The wall is then reduced to one thickness of brick and extended about 6 inches above the grates. This keeps the filling of the furnace in place and prevents it from falling back into the firebox. The filling is banked up against this wall and gradually slopes up to the highest point, which is about 1½ feet beyond the center of the pan. Beyond this point the filling slopes gradually downward to the last compartment of the pan, where it drops off suddenly. If dirt is used for this filling, it should preferably be covered with a layer of brick cement or hard clay to keep the contour of the filling from being changed by a strong draft.

A 3- by 4-inch damper in the chimney may be used to regulate the draft. Enough air to give good combustion of fuel should be admitted. With proper draft, the flames should extend slightly beyond the arch of the chimney.

The evaporator is set on a single line of bricks, which are laid lengthwise on a double-thickness brick wall, flush with the inside surface of the wall. It should be level from side to side, and about 1 inch lower at the front, or juice end. A good joint between the furnace and evaporator is conveniently made with clay or mortar. With the width of furnace given in figure 11, about an inch of each side of the metal bottom of the evaporator projects over the outside edge of the single line of brick, giving an air space that protects the wooden sides from the fire. The front of the evaporator should be within 6 inches of the front of the furnace. A space of 1 to 2 feet between the front of the chimney and the back of the evaporator is desirable. A small crack is sometimes left next to the back end of the evaporator to admit air to the chimney end of the furnace, the draft thus created preventing too close contact of the flame with the sirup end of the pan. As shown in figure 11, the top of the opening into the chimney should be 12 inches below the bottom of the evaporator.

OPERATION OF EVAPORATOR

The evaporator should be thoroughly clean when operation is started. If sediment from the previous operation has been deposited on the bottom and sides, a copper evaporator may be cleaned by allowing a hot dilute solution of hydrochloric (muriatic) acid to stand in it for a short period. This partially dissolves the sediment, so that it can be removed by slight scrubbing while water is run through the pan. As galvanized iron, however, is badly corroded by contact with acid, such evaporators should not be cleaned with acid. Evaporators may be cleaned also by boiling water in them and scrubbing, but this is laborious and time-consuming. The evaporator should be cleaned thoroughly every 2 or 3 days, depending largely on the quantity of deposit adhering to it. When two juice evaporators are in use, it is convenient to clean one every day and use the other for evaporating the first supply of juice in the morning.

When operating during the day only, the evaporator should be kept partly full of water overnight. This can be accomplished satisfactorily by flooding the pan with water after drawing off as much sirup or semisirup as possible. At the end of the day the evaporation need have reached only the semisirup stage. If the semisirup is well skimmed before removal, in the morning it may be put back into the sirup end of the evaporator. The sirup compartment is shut off from the rest of the pan by means of a gate until the evaporator is working well again with fresh juice.

Starting with juice in the pan over only two-thirds of its length, with either water or semisirup in the sirup compartment, blocked off with a gate, is the easiest way to begin the day's operation. Transferring juice or sirup of low density to parts of the pan where the sirup

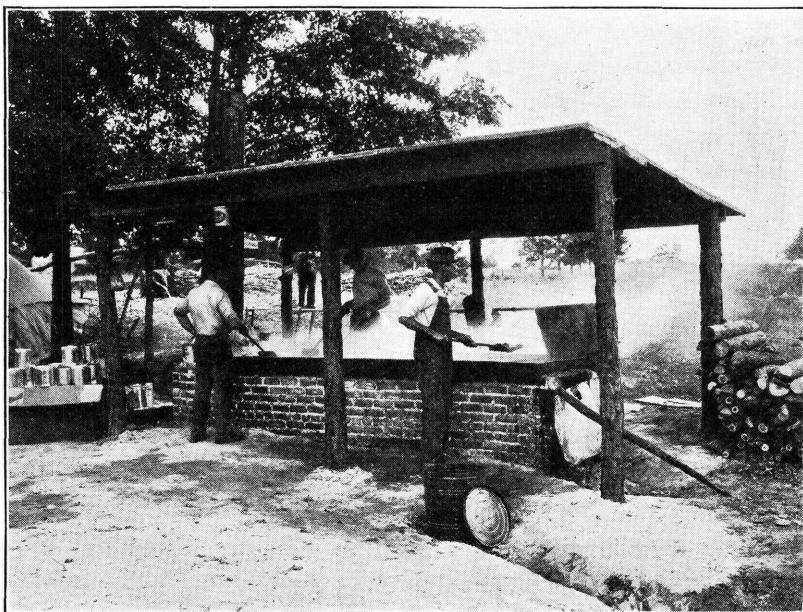


FIGURE 12.—A continuous-type evaporator in operation.

is becoming too dense is bad practice, but it is sometimes unavoidable at the start. As soon as sirup is being finished in the back compartment of the evaporator and clean semisirup is being made from the fresh juice, it is time to permit a continuous flow of juice. The flow of juice ordinarily should be kept as nearly constant as possible without dipping from one compartment to another. Such dipping detracts from the clarity of the sirup, owing doubtless to the mixing of juice and sirup at different stages of clarification. Mixing of high- and low-density juice usually causes a persistent cloudiness in the finished product. The rate at which juice is run into the evaporator and sirup is run out is now controlled by the sirup maker. Most of his time is occupied in keeping the flow well regulated. His station is at the sirup end of the pan (fig. 12), where he can constantly watch the density of the sirup during the final stage of concentration and correct any irregularities. The sirup maker should tell the fireman when the fire needs

attention; a steady fire is necessary to regulate the evaporator properly.

When the evaporator has begun to work well, the juice seldom boils in the first compartment, which is the coolest part of the evaporator, unless for some reason the inflow of cold juice is temporarily stopped. This juice has a smooth, relatively cool surface, over which the scum forms a blanket. This is occasionally removed with a perforated skimmer (fig. 13). An extra-wide skimmer is a labor saver. If the furnace is properly constructed, the boiling of the juice increases in vigor toward the back end of the pan as far as the section under which the fire is hottest. This causes the scum to run counter to the flow of juice to the cooler or front portion of the evaporator.

By the time the juice reaches the hottest part of the pan, which is about $1\frac{1}{2}$ feet beyond the middle, it has been evaporated nearly to

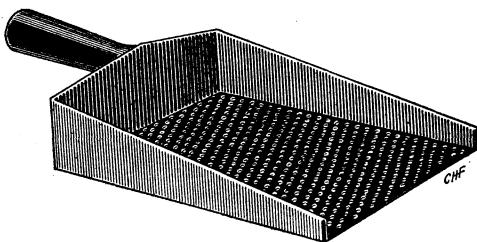


FIGURE 13.—Sirup skimmer.

semisirup density and is fairly well cleaned. As the sirup becomes more concentrated, however, additional impurities separate out, and this material also should be carefully removed by skimming. For efficient skimming, a hot fire must be maintained to "roll" the foam. In addition to firing, the fireman can easily remove skimmings from the cool end of the pan, in this way greatly assisting the sirup maker. Firing at the proper time, however, should be his main consideration.

SKIMMING TROUGHS FOR EVAPORATOR

After the furnace is hot, the foam and skimmings can be made to roll over the edges of the evaporator into troughs built along the sides, so that the skimmings all along the sides of the evaporator will run back through the troughs and collect on the cool juice surface, where they may be more readily removed by a wide skimmer.

Skimming troughs are a great help as they eliminate the necessity of so much hand skimming all along the sides of the evaporator. They make it possible to produce a brighter, clearer, and less turbid sirup, because the skimmings are floated over the sides of the evaporator with the foam and are less likely to be boiled-in. They also reduce loss of sirup. A skimming trough may be attached to each side of an evaporator at practically no expense. A piece of 1- by 4-inch smooth lumber of the same length as the evaporator makes the bottom of each trough, and a similar piece makes the outside wall. Or the troughs may be made entirely of copper or galvanized iron. Some sirup makers prefer troughs 6 inches wide, which may likewise be constructed either of wood or of metal. For the skimming troughs to work well, it is best to have the sides of the evaporator (side bars) not over 5 inches

high (inside measurement); the sides of a deeper evaporator should be cut down.

At the sirup end of the evaporator the bottom of each trough is flush with the top of the evaporator side bar, while at the juice end it is bracketed to the side of the evaporator from 1 to 2 inches below the top. This gives the trough a slope toward the juice end of the evaporator, making the skimmings run that way. A crosswise partition in the center of each trough prevents mixing of the clarified semisirup with the juice. It allows the semisirup skimmings to run back into the middle of the evaporator through a suitable small opening, while the juice skimmings run back into the cold juice through a small section cut out of the evaporator side bars. There are solid ends, of course, in both troughs, so that the skimmings, carried along by a small quantity of foam and juice, will have to run back into the evaporator. This prevents loss of juice.

EVAPORATING TO UNIFORM DENSITY

One of the difficulties most commonly experienced in using a continuous evaporator is that of concentrating the sirup to uniform density. The method of determining the density by weighing a can of the sirup is sometimes used, and when cans are filled uniformly this gives fairly good control. Many operators are able by experience to judge fairly accurately the density of sirup while it is still boiling. Some do this by dipping a skimmer or a sirup "rake" into the boiling sirup, holding it up, and noting how the cooling sirup "flakes off." No amount of experience, however, can take the place of accurate measuring, and the uncertainties of guessing the density by the flaking-off method can be easily eliminated by the use of a sirup-maker's thermometer. Sirup from different varieties of sorgo boils differently. A good thermometer is more useful in the operation of a shallow evaporator than is the hydrometer, often recommended for the purpose. In using the hydrometer, it is necessary to draw off a cylinder of sirup from the evaporator and float the hydrometer in it (fig. 9). This procedure is troublesome when using a shallow evaporator, because the sirup is in such a thin layer that it is not easily dipped out. The hydrometer, although very useful when sirup is made in a deep evaporator by the batch or noncontinuous process, is considered less valuable than a sirup-maker's thermometer for use with the shallow continuous evaporator.

The thermometer most suitable for the purpose is one protected by a substantial copper case, and with a 10-inch scale graduated from approximately 50° to 250° F. The bulb of such a thermometer should be very close to the bottom of the protecting copper case but should not quite touch it. If the bulb stands too high in the case, a little of the bottom of the centerpiece in the case may be cut off. This design is necessary in order that the thermometer bulb may be entirely covered by the shallow layer of boiling sirup (three-fourths of an inch deep). The bulb, however, should not touch either the bottom or side of the evaporator. By providing a broad metal backpiece so that they will stand up, such thermometers may be kept continuously in the sirup to indicate accurately the point of final evaporation, when the sirup should be allowed to run out of the evaporator. Even though the thermometer is used only to check the sirup-maker's guess as to the proper density, it will prove very useful. Sirup which tests 40° to

41° Baumé (74° to 76° Brix) at ordinary temperature, using a hydrometer, boils at 227° F. at sea level at the time when it should be allowed to flow from the evaporator. In testing a sirup for its density in this manner it is well occasionally to determine the accuracy of the thermometer by placing it in boiling water and noting the boiling point. Water should boil at 212° at sea level, 211° at an altitude of 500 feet, and at 210° at an altitude of 1,000 feet. For every 500 feet above sea level, roughly speaking, the boiling point is lowered 1°, so that, when using an accurate thermometer at a point 500 feet above sea level, finished sirup would boil at 226° and at 1,000 feet above sea level it would boil at 225°. The sirup is usually finished at a temperature 14° to 15° higher than the boiling point of water if a sirup of fairly heavy density is desired, although a slightly different finishing temperature may be adopted equally well. The bulb of the thermometer should be cleaned by scouring from time to time; otherwise it may not give an accurate temperature reading.

The sirup density may be checked, if desired, by means of a sirup-maker's Baumé hydrometer (fig. 9). Sirup of good density, when tested at close to the boiling temperature, should be about 35° to 36° Baumé. At ordinary temperature this same sirup will test about 39° to 41°. Sirup testing 40.5° to 41° at ordinary temperature weighs about 11.5 pounds per full United States gallon (no. 10 cans do not hold a full gallon).

REMOVING SEDIMENT FROM SIRUP

Some sirup makers experience difficulty with an excessive amount of sediment. This depends as much on the type of soil on which the crop was grown, the variety of sorgo, the fertilizer used, the kind of growing season, the maturity of the crop, and the juice extraction obtained as upon the skill of the operator. Straining the sirup when boiling hot, using cloth strainers through which the sirup will pass within a reasonable time, does not remove much except the coarser sediment. Moreover, when it has cooled to atmospheric temperature, the sirup at final density cannot be filtered efficiently on the farm by any known means. Sedimentation is in general the most feasible procedure for removing this material from sirup.

Sirup that contains an excessive quantity of suspended material should remain in a settling trough or tank until this material has settled to the bottom. This takes overnight and sometimes even longer. Clear sirup may then be drawn off from the top and barreled, or reheated and canned, and to avoid loss of sirup the layer of sediment, if it contains much sirup, may be returned to the juice.

It should be remembered that the sirup should be allowed to settle when warm but not too hot. Wooden troughs or insulated tanks, which should be covered, may be used to keep the sirup warm and thus facilitate sedimentation. It is considered better practice before running it to the settling tanks to cool it to about 140° F. to prevent the deterioration in quality which is caused by too long a retention of high temperature, and then permit it to settle for a longer period. Sirup that has settled overnight should be reheated for canning (p. 37).

HOW TO PREVENT SLOW BOILING, SCORCHING, AND CLABBERING

Owing primarily to the presence of starch in the juice, difficulty is often experienced in trying to evaporate sorgo juice rapidly to sirup of

the proper density without scorching or burning. Instances occur rather frequently when the sirup end of the evaporator seems to be doing no real evaporating. The heat does not circulate well in the sirup, and the partly evaporated sirup does not boil freely. In such cases it is impossible to concentrate to sufficient density without having the sirup "burn" on the evaporator, thereby producing a greatly inferior sirup, a sirup of dark color and of bitter, strong, and burnt flavor. If density is determined by a thermometer or hydrometer, such sirup scorches before the correct finishing-off point is reached.

Sorgo sirup, moreover, sometimes clabbers or jellies after it is made. This seems to occur particularly with sirup from certain varieties of sorgo and in some years more than in others. For example, extreme drought followed by rain, which often causes excessive branching, seems to cause slow boiling, scorched sirup, and clabbering. The degree of maturity of the crop is undoubtedly another governing factor, as sirup from overripe sorgo has been found especially susceptible to such troubles. The various factors that contribute to this difficulty are not yet fully understood, although starch is undoubtedly largely responsible. What might seem to be a rather small percentage of starch has been found very injurious in sirup making.

Overripe sorgo, which contains a larger percentage of starch than does sorgo at the proper stage of maturity for sirup making, may be harvested in such a manner as to partly remedy the difficulty due to starch. The two uppermost internodes below the peduncle contain much more starch in proportion to the juice, as well as more acidity and mineral matter, than is found in the rest of the stalk (table 4). Accordingly, by discarding at least two, or possibly as many as four, of the top joints, which can often be utilized for animal-feeding purposes, a fairly good grade of sirup can be produced from the rest of the stalk, even when it is overripe. This practice may at times make it possible to save a crop of overripe sorgo, and is advisable when the sirup maker does not have a supply of high diastatic malt extract.

Scorching thick sirup is a difficulty often experienced in open-pan evaporation. Such sirup acquires a red color and a burnt flavor. Scorching is accompanied by a white puff of vapor, and can always be detected by careful observation. Experienced sirup makers detect it by odor almost instantly. Scorching is caused by local overheating of the sirup. Sometimes poor furnace construction is the cause of this; sometimes the sirup is so viscous that the heat circulates through it poorly. Sediment adhering to the bottom of the pan may result in a scorching area. Scorching from this cause may be stopped by thoroughly scraping the surface over which it occurs, care being taken, of course, not to damage the pan. In case the sirup is of too high density at the point where the scorching occurs, sirup of lower density should be forced in from the next compartment.

As early as 1864 Joulie, in a French publication, described the starch in sorgo juice and recommended the use of alcohol in clarification. In 1923 Sherwood, in the journal "Industrial and Engineering Chemistry," reported analyses giving the starch content of the juice of 15 varieties and stated that treatment of the juice with malt diastase increased the rate of filtration of the juice and prevented subsequent jelling of the sirup. The methods for removing starch

given in the present bulletin were developed in detail by the authors to meet the conditions of farm-scale sirup production.

USE OF DIASTASE ON SEMISIRUP

The use of diastatically active malt extract on the raw juice has been described on page 19. This method of treating the juice is still followed by some sirup makers, but the preferred method is to use the diastatically active malt extract, or other commercial diastase preparation, on the semisirup. Less malt extract is required when used on the semisirup, and the finished product tends to be clearer, or brighter, and of better flavor. The cost for the required amount of malt extract is only about one-quarter as much as when malt is used on the juice, although at times somewhat larger amounts have been found to give still better results. When used on semisirup, the cost for diastase is about one-eighth to one-quarter cent per gallon of finished sirup. The details of the process recommended for using malt extract of high diastatic power on the semisirup are as follows:²

The cold juice from the mill is allowed to settle as usual for 2 hours before it is run into the juice evaporator. This settling is supplementary to the usual careful straining, and has been found to be well worth while, as considerable quantities of starch often settle out of the juice.

The juice is next evaporated with careful skimming, as usual, but at first only to semisirup density, which should be held as closely as possible at 20° Baumé, measured at a temperature close to the boiling point. The density of the semisirup is controlled preferably by use of a Baumé spindle, or hydrometer. The semisirup is run out of the evaporator into a holding tank or barrel for the malt treatment before the evaporation is completed.

The semisirup is allowed to cool to 160° F. before the diastatic malt extract is added, as too high a temperature is injurious. The malt extract is added to the semisirup at 160° in the proportion of one-half a pound to 1 pound per 50 gallons of the semisirup, and thoroughly stirred in. Invertase also may be added after the temperature has dropped to 140° (p. 35), if treatment to prevent cane-sugar crystallization is also being given. The holding tank or barrel should then be covered, to keep out dirt and hold the heat. After standing overnight, the semisirup is drawn off and evaporated to sirup density in a finishing-off pan.

To avoid loss of sirup, the small quantity of semisirup and sediment that remains in the bottom of the settling tank when it is nearly empty may be removed through the wash-out connection and returned to the next batch of fresh juice. When empty, the tank should be carefully washed before it is refilled with semisirup.

Although it is best to have the equipment on a hillside, to make use of gravity flow throughout (fig. 2), a convenient procedure for handling the semisirup when the equipment has to be set up on level ground is to transfer it from the evaporator, kettle, or batch pan in small batches or continuously to a pail, bucket, or tub, and then pump or pour it into a holding and settling tank. This tank should be elevated from the ground and should be provided with a draw-off pipe and wash-out opening with suitable valves. The tank should

²The authors gratefully acknowledge the cooperation of Martin Nelson and C. K. McClelland, agronomy department, University of Arkansas, in supplying working facilities and in connection with the agronomic work of this investigation.

be elevated sufficiently to allow the semisirup, when ready, to run by gravity directly into the finishing-off pan, the tank also being sloped about an inch toward the draw-off end. The draw-off line should be from 1 to 2 inches from the bottom to avoid drawing off any sediment.

The semisirup should be allowed to stand overnight in order that the malt extract may have sufficient time to react, and to permit thorough settling. For continuous operation, therefore, two settling tanks should be provided. Each tank should be not over 3 feet deep and of sufficient capacity to hold a day's run of semisirup. When operating continuously, one tank is filled and one is emptied each day. Well-constructed cypress tanks of planed lumber provided with covers hold the heat very well, thus permitting efficient settling. Tanks made of wood and lined with thin copper, however, make the best settling tanks. It is best not to use galvanized iron, as this soon becomes corroded. The tanks for semisirup are inexpensive, as they

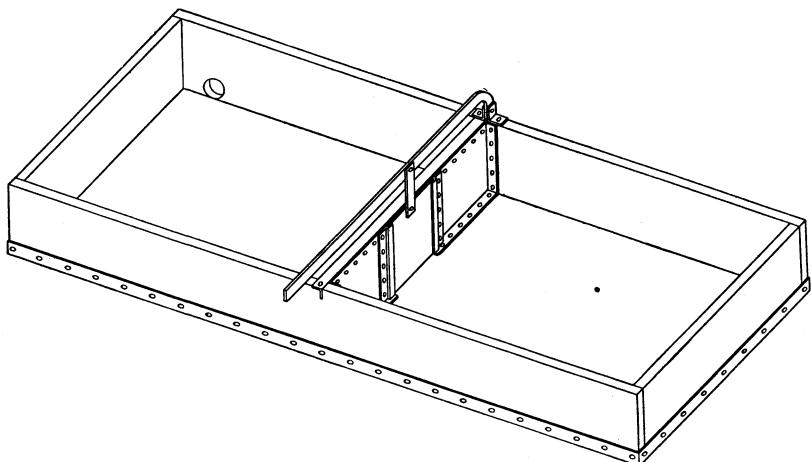


FIGURE 14.—Finishing-off pan. This model is 7 feet 6 inches long, 2 feet 8 inches wide, and 10 inches deep. It should be provided with a tight-fitting gate that is easy to open and close. The furnace is smaller but similar in design to that shown in figure 11.

can ordinarily be made at home. Clean wooden barrels with covers are satisfactory for holding small quantities of semisirup overnight.

FINISHING-OFF PAN

The finishing-off pan recommended for evaporating semisirup to the finished sirup density may be home-made, with cypress or poplar sides and galvanized-iron or, preferably, copper bottom, or it can be made entirely of metal by a local tinsmith. When a 12-foot continuous pan is used in evaporating juice to semisirup, a small batch pan about 5 feet long by $2\frac{1}{2}$ feet wide by 8 or 10 inches deep is large enough for evaporating the semisirup to sirup. By use of a larger batch pan, however, as shown in figure 14, the sirup can be made faster, which is an advantage when the sirup maker wishes to finish earlier in the day so as to give his attention to other work. This batch pan should preferably have a center partition provided with a tight-fitting gate, and be mounted on a suitable furnace of its own.

The finishing-off pan may be so mounted on a furnace that it can be lifted off the fire on to suitable supports when the sirup is finished,

or preferably, when the pan has a good gate, a "pusher" or "rake" may be used to help run the batches of finished sirup out. Semisirup from the other compartment should then be run in immediately to keep the bottom of the pan covered and thus prevent scorching. The draw-off opening, which should be flush with the bottom of the pan, should be 2 to 3 inches in diameter to permit running batches of sirup out rapidly.

Those who use kettles or larger batch pans, instead of continuous evaporators, for sirup making can use these for evaporating semisirup to finished sirup density. Moreover, with certain changes in an evaporator and method of operating it, sirup makers who are using continuous evaporators can make semisirup and finished sirup on the same evaporator at the same time. As previously stated, however, a separate batch pan is very convenient to supplement a continuous evaporator, and makes possible an increased daily production of sirup, owing to the increased boiling capacity. In addition, it is easier to handle a separate batch pan than to make both semisirup and finished sirup on the same evaporator. The extra cost is small, considering its value.

The sirup can best be evaporated to uniform density in a finishing-off pan by using either a Baumé hydrometer or a sirup-maker's thermometer. In ordering sirup-maker's thermometers and Baumé hydrometers, it is best to mention that they are to be used in making sorgo sirup. The malt extract ordinarily sold locally for general home use does not have much diastatic activity and is not suitable for sirup making. The Carbohydrate Research Division, Bureau of Chemistry and Soils, United States Department of Agriculture, will supply the names and addresses of firms from whom malt extract, papers for testing the acidity of the juice, Baumé hydrometers, sirup-maker's thermometers, and invertase may be obtained.

HOW TO PREVENT SUGARING

Sugaring, or crystallization, depends largely upon the variety of sorgo and its maturity. The degree of sugaring depends partly upon the density of the sirup, more crystallization, of course, being experienced with thicker sirups. Stirring the finished sirup while it is cooling, or afterwards, causes more rapid sugaring.

Crystallization may be prevented by mixing the sirup with commercial glucose, or corn sirup, but this procedure cannot be used in making a product to be sold as pure sorgo sirup. Moreover, in seasons when sorgo sirup is plentiful, the cost of corn sirup in small quantities is likely to be so high that there would be little or no profit on the additional gallons of sirup produced by using the corn sirup. The small-scale sirup maker would thus have an additional quantity of sirup to market with difficulty at a time when prices are low.

Excessive crystallization of the sugar dextrose often causes the sirup to become nearly solid with a mass of soft, light-colored, ball-like clumps. This should not be confused with clabbering. The sugar dextrose forms very small, needle-shaped crystals, and has an entirely different appearance from ordinary cane sugar. Cane sugar, or sucrose, usually takes the form of hard, sharp, glistening crystals, shaped like those of table sugar. These two kinds of sugaring do not occur in the same sample of sirup, although both kinds of sugar in varying proportions are contained in all sorgo sirup. Fortunately, the kind

of sugar that crystallizes in the sirup can be determined easily by its appearance. A small hand lens or magnifying glass is helpful in determining the shape of the sugar crystals. It is necessary first to know definitely the kind of crystallization before attempting to apply a remedy. In sorgo sirup, dextrose crystallization occurs nearly as often as does sugaring due to cane sugar.

Crystallization of the sugar dextrose occurs more commonly with some varieties of sorgo, and cane-sugar crystallization is more likely to occur with others. The degree of maturity of the crop is an important governing factor, as is also the kind of growing and harvesting season. Varieties that are most suitable for sirup making in the Southern States may not be best for cultivation farther north. The county agent and the makers of best-quality sirup in the neighborhood can often advise as to what varieties of sorgo are most suitable for local use. As a rule, it is better to choose varieties that never give dextrose crystallization, because cane-sugar crystallization may be more easily controlled.

If trouble with sugaring is still experienced after growing the locally recommended varieties of sorgo and harvesting at the proper stage of maturity, and the sugar has been identified as either dextrose or cane sugar, the following remedies are suggested.

DEXTROSE CRYSTALLIZATION

Sirup in which dextrose crystallization has occurred may be mixed or blended, with heating, with sorgo sirup that has not sugared, or with sorgo sirup that is beginning to deposit cane-sugar crystals. The proportions usually satisfactory are equal parts of each sirup. Or if it is known in advance that one variety of sorgo tends to give dextrose crystallization and that another variety usually gives cane-sugar crystallization, the two varieties may be harvested at the same time, mixed at the mill, and ground together to give a juice of more nearly the ideal composition. Neither of these procedures, however, is considered very practicable. Success in preventing crystallization of both dextrose and cane sugar nevertheless depends upon having these sugars present in the sirup in the right proportions.

CANE-SUGAR CRYSTALLIZATION

In some cases the procedure described for dextrose crystallization may be a practicable remedy for cane-sugar crystallization. It is a good plan to discard at least two and preferably three of the top joints of the cane, as these contain a relatively high proportion of cane sugar as well as starch and acids (pp. 5, 6). Another method of preventing cane-sugar crystallization, if variety selection, harvesting at the proper stage of maturity, and low topping fail to give good results, is the "invertase process." This is a practicable process in which an extract of yeast (invertase) is used during manufacture of the sirup. The yeast extract converts a portion of the cane sugar into the two sugars dextrose and levulose, so that the resulting more properly balanced sugar content of the sirup will not deposit either cane sugar or dextrose crystals. The invertase process, of course, should not be used when the trouble to be remedied is due to dextrose.

Invertase is a clear, water extract of yeast and not a chemical in the ordinary meaning of this term. Invert sugar (dextrose and levulose) is just as sweet and wholesome as cane sugar but sugars or crystallizes

much less readily. The invertase process may be used on the semisirup at the same time that malt diastase is being used, but the invertase should be added at a slightly lower temperature. Directions for using invertase are given below.

INVERTASE PROCESS

In brief, the invertase process as applied to sorgo sirup is carried out as follows: The juice from the mill is settled, carefully skimmed, and evaporated as usual in an evaporator, kettle, or batch pan. The evaporation, however, during 1 day's operation is carried only to the semisirup stage, which is about two-thirds of the total evaporation. When it tests 20° Baumé, while still very hot, the semisirup is collected for invertase treatment in a tank large enough to hold the entire day's output. This is the same tank in which the semisirup may be received for treatment with malt extract (pp. 31-32). The invertase is permitted to act on the cane sugar in the semisirup while the malt diastase is acting on the starch, and the sirup sediment is settling out. Moreover, it is a very good plan to arrange to settle the semisirup in order to remove the sirup sediment, regardless of whether or not the use of diastase and/or invertase is being practiced.

The required amount of invertase is now added to the semisirup. As invertase is destroyed at fairly high temperatures, the semisirup must first be at a suitable temperature; it should be allowed to cool to 140° to 145° F. Semisirup which tests 20° Baumé when practically at a boiling temperature will test 22° to 23° Baumé at 140° to 145° F. The quantity of invertase required depends on the volume of semisirup. As invertase is used in relatively small quantities, for accuracy of measurement the required quantity should be measured in terms of a small unit of volume, such as the cubic centimeter. The proportion required ranges ordinarily from 20 to 30 cubic centimeters of invertase for every 100 gallons of semisirup. Small prescription bottles, glass vials, or cylinders, graduated in cubic centimeters, usually sold in drug stores, are recommended for measuring the invertase accurately. The invertase is mixed with a little water (about a pint) and then added to the tank of semisirup. Because of the small proportion of invertase added, the sirup must be well stirred to thoroughly mix it with the invertase. Be sure to cover the tank or barrel, after adding the invertase, so that the semisirup will remain as warm as possible overnight.

Although about 25 cubic centimeters of invertase per 100 gallons of semisirup is usually required, it may be necessary to vary the quantity somewhat in certain cases, owing to differences in the proportion of cane sugar and invert sugar originally present in the juice, the proportion of cane sugar converted into invert sugar during evaporation, and the strength of the invertase. The best way to determine for the first time whether too little or too much invertase has been added is to observe the color and flavor of the first batch of sirup and its tendency to crystallize after evaporation to final density. If the sirup does not differ appreciably in quality from sirup obtained from the same kind of sorgo when no invertase was used, and if no sugar separates from the sirup, it is safe to conclude that the proper quantity has been added. If, however, the color and flavor of the finished sirup differ appreciably from those of sirup of the same density made without invertase, slightly less invertase should be used thereafter. Con-

versely, if the finished sirup shows a tendency to deposit cane sugar, the proportion of invertase used for the next lot should be increased.

The tendency of sirup to undergo cane-sugar crystallization may be easily and quickly tested by permitting a small sample (about a pint in a glass jar) to cool until it is lukewarm and then adding about a teaspoonful of ordinary granulated sugar and stirring occasionally over a period of 2 or 3 hours. If no sugar in excess of that which has been added appears in the sirup after it has stood overnight, the quantity of cane sugar which is likely to be deposited later will be very small at the most. The smallest proportion of invertase that will prevent cane-sugar crystallization should be used, and once this has been determined approximately, the same amount may be used regularly for the same sorgo variety and condition of the crop.³

Since invertase does not act instantaneously, a certain period is required for it to convert the necessary quantity of cane sugar into invert sugar. It has been found convenient to allow approximately 12 hours (overnight) from the time the invertase is added to the semisirup until evaporation to final sirup is started. The invertase is usually added at night, and final evaporation of the semisirup is begun when operation is resumed next morning, using the batch or finishing-off pan (p. 32).

In boiling the semisirup to finished sirup density, it is advisable to evaporate as rapidly as possible to avoid altering the flavor of the sirup. Start with a small fire and stir the thin semisirup until it is hot; then evaporate rapidly, paying attention as usual to careful skimming. It is best to work with rather small batches.

By using the invertase process on sorgo semisirup, as described above, the cost for invertase is only one-quarter to one-half a cent per gallon of final sirup. Those who have serious trouble with cane-sugar crystallization will find this process very much worth while. Proper canning is depended upon to prevent fermentation of sirup of 40° to 41° Baumé density.

CANNING

As sirup has been thoroughly sterilized by boiling, it does not ferment if packed while hot in clean containers and sealed immediately. The cans or glass containers must be airtight; otherwise, fermentation or molding may occur. Large containers, like kegs and barrels, should be thoroughly washed several times with boiling water or, if possible, steamed, and then dried before sirup is put into them.

As the sirup flows from the evaporator, strain it through muslin, or light domestic. Allow it to cool somewhat either for canning or for barreling, as excessive canning temperatures impair the quality. An inexpensive and very convenient arrangement for cooling the sirup consists of one or more screened cooling troughs into which the sirup may be run, or poured, and which are high enough off the ground to allow it to run into the cans by gravity. For filling half-gallon and smaller cans the sirup should be at a temperature of 190° F. or as close to it as possible; for gallon cans, it should be 180°; and for barreling, the sirup should be cooled to at least 120°. These temperatures are recommended for farm-scale sirup canning; somewhat lower tem-

³ To test the tendency of sirup to undergo dextrose crystallization, another sample of the sirup may be "seeded" with commercial dextrose, which is commonly called corn sugar.

peratures may be used by canning plants where large stacks of sirup in cans hold the heat for a longer time.

Sirup that has been allowed to stand for some time in order to remove the sediment should be reheated to the proper temperature for canning. For this purpose, the loosely sealed cans, nearly filled with well-settled sirup, may be placed on a low rack in the evaporator and heated by means of boiling water in the evaporator. When a thermometer shows that the sirup is at the proper temperature, the cans may be removed and sealed. This method, although troublesome, is preferable to canning sirup directly from the evaporator when it contains an excessive amount of dregs or sediment. The use of a steam-jacketed kettle or a tank provided with steam coils is best for reheating the sirup, but this equipment is seldom available on the farm.

MARKETING

It is sometimes worth while for all the sorgo-sirup producers in one locality to cooperate in marketing their product. A system of grading then becomes imperative. As a rule, buyers expect uniform quality even though the sirup is bought at different times and from different manufacturers. They are not informed regarding manufacturing conditions and do not understand why all sorgo sirup does not have the same taste and appearance. By fixing standards, it is possible to grade sorgo sirup as to color, flavor, clarity, and density. A system of grading makes it possible to market the sirup to better advantage.

COMPOSITION OF SORGO SIRUP

Table 6 shows the sugar and nonsugar content of several samples of sirup made from different varieties of sorgo grown at one location in Mississippi. The varieties were cut at approximately the same stage of maturity, and all samples were carefully stripped. They were harvested in the usual farm manner, only the customary length of tops and butts being discarded. The percentages of sucrose, invert sugar, mineral matter, and organic nonsugars are based on the total weight of the sirup at a uniform density of 76 percent of total solids, or a water content of 24 percent.

TABLE 6.—*Composition of sorgo sirup*

Variety	Sucrose	Invert sugar	Mineral matter	Organic non-sugars	Variety	Sucrose	Invert sugar	Mineral matter	Organic non-sugars
Gooseneck-----	Percent 35.26	Percent 34.99	Percent 1.38	Percent 4.37	Kansas Orange-----	Percent 39.70	Percent 29.26	Percent 2.13	Percent 4.91
Iceberg-----	49.72	20.63	1.38	4.27	Wisconsin Orange-----				
Hodo-----	29.33	40.90	1.29	4.48	Honey-----	48.26	18.41	2.24	7.09
Red X-----	39.94	26.24	3.14	6.68	Japanese Seeded-----	29.16	40.71	1.68	4.45
Leoti Red-----	42.34	27.57	2.49	3.60	Ribbon Cane-----	29.83	42.05	1.58	2.54
Folger-----	40.85	27.94	2.77	4.44	Hastings-----	46.94	21.34	1.73	5.99
Red Amber-----	45.35	21.20	2.57	6.88					

COST OF MAKING SIRUP

The following tabulation gives the itemized costs of materials, equipment, and labor required to construct a relatively large farm sirup-making outfit, including a power mill suitable for grinding 10 tons of sorgo per 10-hour day, and making 100 to 200 gallons of sirup

daily. These costs vary somewhat from year to year and also for different localities.

Lumber and building supplies, tanks, piping, etc.	\$150.00
Brick, lime, sand, etc., for furnace	50.00
Grates for furnace	30.00
Labor for building sheds and furnace	50.00
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Total cost of building and furnace	280.00
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Mill and accessories	250.00
12- to 15-foot copper evaporator	50.00
Engine and freight	200.00
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Total cost of equipment	500.00
	<hr/>
Total investment	780.00
Interest at 6 percent and depreciation at 10 percent for 1 year	124.80

The itemized daily cost of operating this plant is:

1 sirup boiler	\$2.00
1 fireman	1.50
1 mill feeder	1.50
1 bagasse carrier	1.00
	<hr/>
Total labor	6.00
Wood, at \$2.50 per cord	5.00
Oil	.75
Gasoline (12 gallons, at 25 cents per gallon)	3.00
	<hr/>
Total operating cost per day	14.75
Operating cost for 45 days (14.75 \times 45)	663.75
Interest at 6 percent and depreciation at 10 percent for 1 year	124.80

Total manufacturing cost for season's operations 788.55

Assuming that 10 tons of sorgo are ground per day and that 15 gallons of sirup per ton of stalks are obtained, the output of sirup in this plant during a 45-day season would be 150×45 , or 6,750 gallons.

The manufacturing cost, exclusive of cost of the sorgo, is 11.7 cents per gallon. The cost for the sorgo per gallon of sirup, assuming a value of \$5 and a yield of 15 gallons of sirup per ton of stalks, is 33.3 cents per gallon. The total cost for the sirup, therefore, is 45 cents per gallon. If the sirup sells at 50 cents a gallon, the net profit is 5 cents per gallon. Therefore, the profit for a 45-day season would be \$377.50. In addition to this, the farm family often supplies most of the labor, thereby saving the expense of hired help.

The sirup producer who grows only half an acre to 3 acres of sorgo usually finds it more economical to have his sirup made on shares at a custom mill, which is the preferable plan, or else to use a small animal-power mill with a capacity of 3 to 5 tons daily, and a 10-foot pan or evaporator having a capacity of 50 to 75 gallons of sirup per 12-hour day. The initial cost of such equipment is estimated at \$150 to \$200, with a simple shed for the evaporator. The costs of operation and upkeep are also small.

BYPRODUCTS

BAGASSE

The crushed sorgo as it comes from the mill is known as bagasse, but it is sometimes called pomace or chews. It may be used as bedding material for farm animals or as a temporary filling for low

and muddy places on the farm. When properly composted and then spread over fields and plowed under, it is of some value in supplying humus and improving soil texture. In some sections it is customary to give cattle access to the bagasse which has been spread over the fields, care being taken not to let them eat too much of it at first. As bagasse resulting from good milling practice is mostly fiber or cellulose, it has relatively little value for feeding. Bagasse finely chopped and mixed with varying proportions of cottonseed meal, molasses, etc., has, however, been used as a cattle feed.

SEED HEADS

The quantity of seed per acre differs with the variety of sorgo and the stand. Estimates range from 5 to 30 bushels to the acre, average figures for the usual varieties being from 10 to 15 bushels. They have a high feeding value, claimed by some to be equal to corn, although most authorities give them a place below corn. On account of the shape and hardness of the seed, better feeding results are said to be obtained by first boiling or grinding them. Because of the difficulty of removing the hulls, and the astringency of the seed coating, the grain is said to be relished by animals less than is that of the nonsaccharine varieties of sorghum. It has been claimed, however, that sorgo seed, properly prepared, is very good feed for poultry, and some authorities have estimated that each acre of sorgo will furnish enough seed to fit one hog for market.

SKIMMINGS

Skimmings have recognized value in feeding farm animals, especially hogs. As this sometimes results in scouring, however, the quantity fed at any one time should be limited to the amount which experience has shown to be safe.

LEAVES AND TOPS

In stripping, from 5 to 15 percent of the weight of the crop is removed from the stalks. In general, when green the leaves weigh on an average about 10 percent of the topped sorgo. If they are frostbitten or dry, or both, they may not be over 4 percent of the weight. When buying sorgo, some sirup makers consider a long ton of unstripped material equivalent to a short ton of stripped material, that is, 2,240 pounds are equivalent to 2,000 pounds, which would make the leaves and dirt amount to 10.7 percent. As some varieties have more leaves than others, only average figures can be given. The above data are for sorgo topped in the usual manner. After wilting and curing a little, the leaves may be eaten by cattle, or if left in the fields and plowed under, they are of some value as humus. They have also been used in making silage, along with the tops. When two to four top joints of the stalks are discarded in making sirup (pp. 5-6), the value of the tops for feeding purposes is an important item. Owing to danger of cyanide poisoning, the leaves and tops should be wilted and cured somewhat, or else made into silage before they are fed to cattle.

The combined value of the byproducts in the production of sorgo sirup is an important consideration in evaluating the crop.

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